# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

ANALYSIS OF THE HISTORICAL RELATIONSHIP
BETWEEN CURRENT NAVY RDT&E AND
FUTURE INVESTMENT IN PROCUREMENT

by

Edward Charles Long, III

December 1978

Thesis Co-Advisors: J.M. Fremgen
H.J. Larson

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In partial response to a memorandum for the Superintendent, Naval Postgraduate School, from the Director of the Fiscal Management Division, Office of the Chief of Naval Operations (Serial 922E21/58726 dated 24 April 1978), this thesis attempts to analyze the historical relationship between the Navy's investment in current RDT&E and future investment in procurement. Utilizing data from fiscal years 1962 through 1979 and single

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Eight separate models are developed, and analysis of results indicates the existence of a predictive relationship. However, there are also indications that the basic relationship may have changed during the period under study. The relative inaccuracy of forecasting methods when earlier data are ignored makes the usefulness of these procedures to those who shape future Navy budgets difficult to determine.

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# Analysis of the Historical Relationship Between Current Navy RDT&E and Future Investment in Procurement

by

Edward Charles Long, III
Lieutenant Commander, United States Navy
A.B., Dartmouth College, 1966

Submitted in partial fulfillment of the
requirements for the degree of

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## ABSTRACT

In partial response to a memorandum for the Superintendent, Naval Postgraduate School, from the Director of the Fiscal Management Division, Office of the Chief of Naval Operations (Serial 922E21/587526 dated 24 April 1978), this thesis attempts to analyze the historical relationship between the Navy's investment in current RDT&E and future investment in procurement. Utilizing data from fiscal years 1962 through 1979 and single equation econometric forecasting techniques, linear models predicting procurement one to four years in advance based on current RDT&E are developed. From time-series data, with the models adjusted for serial correlation of the error terms, ex post forecasts and confidence interval estimations are used to evaluate the extent and usefulness of the predictive relationships discovered.

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# I. INTRODUCTION

The analysis to be conducted in this thesis was originally proposed by a memorandum from the Director of the Fiscal Management Division, Office of the Chief of Naval Operations, to the Superintendent of the Naval Postgraduate School.[1] Appendix A contains a copy of that correspondence, which expressed concern that more and more promising new weapons programs were being terminated because their estimated procurement costs made them unaffordable. At the same time, the Department of Defense was continuing to increase its research and development efforts. For example, the fiscal year (FY) 1979 Navy Research, Development, Test, and Evaluation (RDT&E,N) appropriation request provided a real program growth of about six percent over the FY 1978 level. The memorandum implied that the increasing complexity and costs of modern systems, at least in part, resulted from earlier research and development effort; and the memorandum expressed an interest in developing, if possible, a predictive model.

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[1]Although the correspondence is officially from the Office of the Chief of Naval Operations (OPNAV) only, its author and most of his subordinates also hold positions in the Office of the Navy Comptroller (NAVCOMPT) under the Secretary of the Navy. To avoid confusion, future references to this correspondence, the analysis or the persons who conducted it will use the modifier "OPNAV/NAVCOMPT".

Specifically, based upon the current investment in research and development, can future procurement requirements be predicted? The OPNAV/NAVCOMPT staff conducted a preliminary study in pursuit of this question, and a discussion of their analysis follows.

## A. THE OPNAV/NAVCOMPT ANALYSIS

The analysis conducted by the OPNAV/NAVCOMPT staff was limited to eighteen individual development/procurement programs included in the FY 1979 budget submission. These programs were all in the engineering development stage and had progressed to the point of having budget quality estimates of both total research and development and procurement costs through the program years (the four years beyond the budget year) [Refs. 4 and 5]. For each of these programs a ratio of total procurement costs to total research and development costs was calcuated. This ratio was then adjusted or weighted by the program's fraction of the FY 1979 RDT&E,N sample.[2] The sum of these individual weighted factors then equated to the relationship between research and development and procurement costs: for every dollar of RDT&E,N, the Navy could expect to spend approximately four dollars procuring the associated weapons systems.

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[2]Weighted Factor = Procurement to RDT&E,N Ratio x [Program FY 79 RDT&E,N ÷ Total Sample RDT&E,N].

The limitations of such a study are more or less obvious. The study addresses only a single year's data, and much of those are estimated. There exists a wide variance among the calculated procurement to research and development ratios (from a high of 33.2 to a low of 0.4). Thus, what may be true for this sample may not necessarily be true for a different one. The amount of RDT&E,N money included in the study represented only 25 percent of the total RDT&E,N budget request. Finally, the ratios of procurement to research and development were apparently calculated without adjusting costs to consistent or constant dollar figures. The study mixed dollars of past, present, and projected future purchasing power. Adjusting for this difference would not be an easy task in light of the way in which the data were presented.

# II. AN EXPANDED STUDY

This thesis will expand the study of the relationship between procurement and research and development costs. Investigation of possible methods of conducting this expanded analysis produced two general alternatives:

## A. ALTERNATIVE METHODS

### 1. The Micro Approach

This alternative would proceed in an effort to identify individual programs for which RDT&E,N and procurement investments had been made. These data could then be aggregated to provide a basis for estimating the overall relationship of procurement to research and development in much the same manner as the OPNAV/NAVCOMPT analysis. In addition, individual programs could then be categorized in such a manner as to study particular types of systems (e.g. high performance aircraft or surface radar systems).

### 2. The Macro Approach

This alternative would use aggregate historical budget data rather than figures for individual programs. The relationship of total RDT&E,N to a total of the Navy's procurement accounts could be studied, as well as relationships by program budget activity or Department of Defense (DOD) program category (e.g. RDT&E,N for aircraft and missiles versus procurement of aircraft and missiles).

The macro approach was chosen for several reasons. First, pursuit of the micro approach with the thought of logically connecting each dollar spent in RDT&E,N to an item of current or future procurement would have fallen well short of that goal. There is a significant portion of the total RDT&E,N budget, such as basic research and management and support, which could never be "applied" to a particular procurement action in other than an arbitrary manner. Secondly, what historical data we now have concerning the RDT&E,N and procurement monies spent on specific programs are made available mainly through Selected Acquisition Reports (SAR's) which are submitted by the Navy to the Department of Defense. These SAR's provide a means of tracking costs on a regular basis. Unfortunately, these reports cover only major programs (over $75 million RDT&E,N and/or $300 million procurement) and go back only as far as 1970 [Refs. 3 and 6]. Finally, an attempt to trace historical RDT&E,N detailed program element data to procurement data for the major programs or for the myriad of smaller programs would have resulted in an excessively time-consuming data extraction process and, in the end, would still have left much of the RDT&E,N investment unaccounted for.

## B. ASSUMPTIONS AND DEFINITIONS

The most basic assumption underlying any financial analysis is that human behavior can be reasonably and

accurately represented by a dollar figure. More specifically in regard to this study, human behavior which we might define as the "level of effort" in research and development and the "level of effort" in procurement are assumed to be susceptible to representation by dollar figures. But which dollar figure among the many available in the DOD budgetary process best represents these levels of effort? Terms like authorization, appropriation, outlay, expenditure, budget authority, new obligational authority, total obligational authority, budget activity, program, total program, DOD program category, reimbursements, reimbursable, budget plan, and obligation are not easily, widely, or fully understood, in spite of the many text book definitions available.

Appendix B is a glossary which will provide the reader with definitions of terms as they are used in this analysis, but additional explanation of this thesis' answer to the question posed above (i.e. which dollar figure is best) is in order. Table 1 presents a page from The Budget of the United States Government, 1970 - Appendix and will serve as an example of the complexity (and in some cases inconsistency) of terminology and as support for the answer at which we will arrive.

Table 1 presents the schedule of program costs and financing for the Navy's procurement of aircraft and missiles (PAMN) appropriation account for FY 1970. This

# TABLE I

PROCUREMENT OF AIRCRAFT AND MISSILES, NAVY—Continued

Program and Financing (in thousands of dollars)

| | Identification code 07-15-1505-0-1-051 | Budget plan (amounts for procurement actions programed) | | | Obligations | | |
|---|---|---|---|---|---|---|---|
| | | 1968 actual | 1969 estimate | 1970 estimate | 1968 actual | 1969 estimate | 1970 estimate |
| | **Program by activities:** | | | | | | |
| | Direct: | | | | | | |
| | 1. Combat aircraft | 1,535,275 | 1,503,340 | 1,494,100 | 1,683,371 | 1,484,600 | 1,570,300 |
| | 2. Airlift aircraft | ---------- | 15,039 | 36,800 | ---------- | 9,800 | 27,700 |
| | 3. Trainer aircraft | 73,798 | 83,415 | 110,200 | 81,322 | 83,200 | 104,300 |
| | 4. Other aircraft | 4,265 | ---------- | 8,600 | 4,144 | 11,000 | 10,600 |
| | 5. Modification of aircraft | 441,062 | 401,251 | 325,900 | 469,680 | 405,200 | 361,900 |
| | 6. Aircraft spares and repair parts | 606,066 | 373,626 | 584,200 | 632,909 | 390,000 | 553,400 |
| | 7. Aircraft support equipment and facilities | 99,301 | 101,500 | 99,100 | 96,877 | 88,100 | 97,300 |
| | 8. Ballistic missiles | 175,039 | 384,680 | 517,900 | 99,696 | 330,500 | 485,000 |
| | 9. Other missiles | 329,203 | 326,941 | 258,000 | 335,239 | 325,400 | 232,400 |
| | 10. Modification of missiles | 20,820 | 19,345 | 27,000 | 21,275 | 15,400 | 19,900 |
| | 11. Missile spares and repair parts | 25,743 | 21,971 | 38,900 | 13,275 | 20,800 | 27,000 |
| | 12. Missile support equipment and facilities | 29,966 | 16,779 | 23,300 | 20,023 | 16,600 | 22,600 |
| | Total direct | 3,340,538 | 3,248,387 | 3,524,000 | 3,457,811 | 3,180,600 | 3,512,400 |
| | Reimbursable: | | | | | | |
| | 7. Aircraft support equipment and facilities | 29,281 | 26,000 | 26,000 | 14,585 | 15,000 | 15,000 |
| | 12. Missile support equipment and facilities | 17,740 | 21,000 | 21,000 | 19,857 | 20,000 | 20,000 |
| | Total reimbursable | 47,021 | 47,000 | 47,000 | 34,442 | 35,000 | 35,000 |
| 10 | Total | 3,387,559 | 3,295,387 | 3,571,000 | 3,492,253 | 3,215,600 | 3,547,400 |
| | **Financing:** | | | | | | |
| | Receipts and reimbursements from: | | | | | | |
| 11 | Federal funds | −35,310 | −35,300 | −35,300 | −19,233 | −35,300 | −35,300 |
| 13 | Trust funds | −22,317 | −22,300 | −22,300 | −19,589 | −22,300 | −22,300 |
| 14 | Non-Federal sources [1] | −4,394 | −4,400 | −4,400 | −3,991 | −4,400 | −4,400 |
| 21 | Unobligated balance available, start of year: | | | | | | |
| | For completion of prior year budget plans | ---------- | ---------- | ---------- | −1,572,837 | −1,212,814 | −1,202,514 |
| | Available to finance new budget plans | ---------- | −159,000 | ---------- | ---------- | −159,000 | ---------- |
| | Reprograming from prior year budget plans | −243,638 | −90,087 | −75,000 | ---------- | ---------- | ---------- |
| 22 | Unobligated balance transferred from other accounts | ---------- | −410,000 | −25,000 | −7,517 | −410,000 | −25,000 |
| 24 | Unobligated balance available, end of year: | | | | | | |
| | For completion of prior year budget plans | ---------- | ---------- | ---------- | 1,212,814 | 1,202,514 | 1,151,114 |
| | Available to finance subsequent year budget plans | 159,000 | ---------- | ---------- | 159,000 | ---------- | ---------- |
| | Budget authority | 3,240,900 | 2,574,300 | 3,409,000 | 3,240,900 | 2,574,300 | 3,409,000 |
| | Budget authority: | | | | | | |
| 40 | Appropriation | 2,939,100 | 2,574,300 | 3,409,000 | 2,939,100 | 2,574,300 | 3,409,000 |
| 42 | Transferred from other accounts | 301,800 | ---------- | ---------- | 301,800 | ---------- | ---------- |
| 43 | Appropriation (adjusted) | 3,240,900 | 2,574,300 | 3,409,000 | 3,240,900 | 2,574,300 | 3,409,000 |
| | Relation of obligations to outlays: | | | | | | |
| 71 | Obligations incurred, net | | | | 3,449,440 | 3,153,600 | 3,485,400 |
| 72 | Obligated balance, start of year | | | | 3,764,367 | 3,571,799 | 3,120,399 |
| 74 | Obligated balance, end of year | | | | −3,571,799 | −3,120,399 | −3,265,799 |
| 90 | Outlays | | | | 3,642,008 | 3,605,000 | 3,340,000 |

[1] Reimbursements from non-Federal sources are derived principally from cash sales to foreign governments of other aircraft components, and spares and repair parts (22 U.S.C. 2315).

schedule provides actual figures for the previous year (1968) and estimates for the current year (1969) and budget year (1970). It is presented in three main parts: (1) the program-by-activities section, (2) the financing section, and (3) the section on relation of obligations to outlays.

The program-by-activities section presents the results of the executive branch's programming function in terms of financial requirements by budget activity. This classification by budget activity is not consistent throughout the budget for each appropriation nor is it consistent with the DOD classification by program category [Refs. 2, 5, and 7]. The former characteristic reflects the fact that each appropriation account is divided among several budget activities and that these vary from appropriation to appropriation. The latter indicates that DOD program category classification (e.g. strategic forces, general purpose forces, etc.) has an orientation entirely different from the appropriation's program-by-activities section. This necessitates the function known as "crosswalking", or being able to shift from budget appropriation to DOD program and back again [Refs. 1 and 4].

The financing section shows the sources of funds (budget authority, receipts and reimbursements, unobligated balances available and amounts transferred in, etc.) which will be used to support the financial requirements as determined above.

The relation-of-obligation-to-outlays section shows obligations net of offsetting collections at the start and end of each year and presents the actual net cash outflow as a result of the programming and budgeting activity conducted in connection with this appropriation account.

The appropriation (adjusted) section is included when required for the year prior. It merely shows what portion of the appropriation for that year was actually transferred from other accounts.

Selection of that dollar figure which would best represent the level of effort is based upon the definitions of the terms programming and budgeting as they are used in the context of the Federal financial management process. Programming is defined as the process of translating planned military force requirements into time-phased manpower and material resource requirements. Budgeting is defined as the process of translating approved resource requirements (manpower and material) into time-phased financial requirements [Ref. 5]. Where these processes interface, that is, where time-phased manpower and material resource requirements are first stated in terms of financial requirements appears to be the point at which to determine the best financial representative of "level of effort". The dollar figure at this point (refer to Table 1) is the total direct program figure and represents the financial requirements of each budget activity necessary to support approved programs.

This total is the equivalent of the more commonly-used term, total obligational authority (TOA). However, it is not simply new obligational authority plus unobligated balances, which is the most frequently heard definition of TOA [Ref. 1].

For the purposes of this study, the data used will be the total direct program by budget activities for the Navy's Research Development, Test, and Evaluation (RDT&E,N), and the Navy's procurement accounts (PAMN - Procurement of Aircraft and Missiles; WPN - Weapons Procurement; APN - Aircraft Procurement; OPN - Other Procurement; and PMC - Procurement, Marine Corps). These data will be actual historical data in so far as practicable. For fiscal years 1978 and 1979 the data will be estimates only [Ref. 8].

## C. HYPOTHESIS

The general working hypothesis under which the remainder of this analysis will be conducted is as follows: there exists a predictive relationship between current Navy research and development efforts and future investments in procurement.

# III. THE METHODOLOGY

## A. THE DATA

As indicated above, data used in this study will be the total direct program figures for the Navy's RDT&E and procurement accounts. These have been taken from the annually published Budget of the United States Government ...Appendix [Ref. 8] and, except for FY 1978 and FY 1979, will be actual figures. That is, the amounts will originate in the budget plan's "actual" column of the program-and-financing section for each appropriation. For example, the figure for the Navy's 1968 PAMN account is obtained from The Budget of the United States Government, 1970 - Appendix. The total direct FY 1968 PAMN program is $3,340,538,000, as shown in Table 1.

Data were collected for each full fiscal year starting with 1962 and ending with 1979.[3] It was felt that this time span would provide enough data to develop a predictive model if, in fact, such a relationship existed. Of course, the figures contained in the budget documents are in current U.S. dollars, and an adjustment to constant dollars (FY 1979 dollars in this case) was made prior to the conduct of the analysis. Factors for converting current dollars to

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[3]Data from the transition quarter of 1976, designated 19TQ, were ignored by this study.

constant FY 1979 dollars were obtained for each appropriation account as promulgated by DOD on February 10, 1978. Appendix C contains in tabular form the current dollars, adjusting factors, and constant dollars for all of the quantitative data used in this study.

## B. THE MODEL

The basic principles of econometrics and economic forecasting will be used to determine if there exists a predictive relationship between current efforts in RDT&E and future efforts in procurement. This relationship will be described initially by the classical normal linear regression model:

$$Y_t = a + b X_t + e_t \qquad (1)$$

where

$Y$ = the dependent variable,

$X$ = the explanatory variable,

$e$ = a random error term whose values are based upon an underlying probability distribution,

$a$ and $b$ = regression parameters which are unknown,

$X$ and $Y$ are observable but $e$ is not, and

the subscript $t$ refers to the $t^{th}$ observation [Ref. 10].

In this analysis the explanatory variable, X, will always be the RDT&E,N direct program in the budget year (BY), while the dependent variable will be one or a total of the Navy's procurement direct programs for one or more of the program years. Since these observations are made over time, they are often referred to as "time-series data" [Ref. 10]. Thus, the subscript t is used rather than the more common i.

## C. ASSUMPTIONS

In addition to the general form of the model as expressed in equation (1), the classical normal linear regression model must conform to the following basic assumptions.

1. Normality

   The error term, $e_t$, is normally distributed.

2. Zero Mean

   The expected value of the error term, $E(e_t)$, is equal to zero.

3. Homoscedasticity

   Every disturbance, $e_t$, has the same variance, $S^2$, whose value is unknown.

4. Nonstochastic X

   The explantory variable, $X_t$, is nonstochastic (nonrandom) with values fixed in repeated samples and such that, for any sample size,

$$\frac{1}{n} \sum_{t=1}^{n} (X_t - \overline{X})^2$$

is a finite number different from zero. ($\overline{X}$ is the mean value of all $X_t$, and n is the number of data pairs in the sample.)

5. Nonautoregression

The error terms, $e_t$, are uncorrelated in a statistical sense [Refs. 10 and 12].

This analysis assumes that the data conform to all of the basic assumptions listed above except the fifth, nonautoregression. This assumption is most often violated by relations estimated from time-series data [Refs. 9 and 10], and the analysis will proceed on the opposite assumption, determine the extent of autoregression or serial correlation present, and make the necessary adjustments to the model.

## D. PROCEDUREAL DETAILS

For each set of data, certain steps will be taken in the following logical sequence.

1. Ordinary Least Squares (OLS) Regression

The method of least squares will be used to provide estimates of the model's regression parameters a and b where

$$a = \frac{\sum Y_t}{n} - \frac{b\sum X_t}{n}$$

and

$$b = \frac{n\sum X_t Y_t - \sum X_t \sum Y_t}{n\sum X_t^2 - (\sum X_t)^2}$$

This procedure in graphic terms results in a straight line which minimizes the sum of the squared deviations of the data points on the graph from the points on the straight line (with distances measured vertically).

2. The Hildreth-Lu Procedure

Autoregression of the data's error terms has been assumed. The next step is to determine the extent of first order serial correlation present, if any, by using the Hildreth-Lu procedure [Ref. 12] to estimate a new parameter, r, which is the correlation coefficient between errors in time period t+1 and errors in time period t.

In this procedure, a set of values are specified for r, and for each value of r, another OLS regression is conducted and error sum of the squares (ESS)[4] calculated on the following equation.

$$Y_t^* = a(1-r) + bX_t^*$$

where

$$Y_t^* = Y_{t+1} - rY_t,$$

---

[4]ESS = The sum of the squared differences between the estimated and observed values of the dependent variable.

and

$$X_t^* = X_{t+1} - rX_t.$$

The procedure selects that value of r which results in the lowest ESS, guarantees a maximum likelihood estimate of r, and may be repeated until the desired accuracy is achieved, to the nearest thousandth in this instance.

3. Generalized Differencing

By this procedure the original model is changed into one for which the error terms are independent. The result is the transformed equation,

$$Y_t^* = a(1-r) + bX_t^* + v_t, \qquad (2)$$

where

$$Y_t^* = Y_{t+1} - rY_t,$$

$$X_t^* = X_{t+1} - rX_t,$$

and

$$v_t = e_{t+1} - re_t$$

are the generalized differences of $Y_t$, $X_t$, and $e_t$, respectively. The transformed equation (2) has an error process

which is independently distributed with zero mean and constant variance, and an OLS regression applied to it will produce estimates of all the parameters. The intercept of the original model, however, must be calculated from the estimated intercept associated with equation (1) [Ref. 12]. Thus, once the correlation coefficient of the error terms, r, is known or has been estimated, it is a relatively simple matter to adjust the original model.

4. Forecasting

Having completed the procedure as outlined above, the estimates of a(1-r), b, and r as they appear in model (2) have been obtained. These are then substituted into the model along with expressions for the generalized differences of $Y_t$, $X_t$, and $e_t$:

$$Y_{t+1} - rY_t = a(1-r) + b(X_{t+1} - rX_t) + e_{t+1} - re_t$$

A forecast value of $Y_{t+1}$, denoted by $\hat{Y}_{t+1}$ may then be obtained:

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t \qquad (3)$$

The error term, $v_t = e_{t+1} - re_t$, has been dropped from equation (3) for reasons of clarity. Without proceeding with mathematical proofs, the variance of the forecast error which will be used to obtain confidence intervals about the point estimate ($\hat{Y}_{t+1}$) is given by

$$S_v^2 = (1-r^2)\ S_f^2$$

where

$$S_f^2 = S^2[1 + \frac{1}{T} + \frac{(X_{t+1} - \overline{X})^2}{(X_t - \overline{X})^2}] , \qquad (4)$$

$$S^2 = \frac{1}{T-2} \sum (Y_t - Y)^2 \qquad (5)$$

and

T = the number of observed pairs in the original data set.

THe 95% confidence interval using the <u>Student's t</u> distribution for $\hat{Y}_{t+1}$ is

$$\hat{Y}_{t+1} - t_{.025;n-2}\ S_v = Y_{t+1} = \hat{Y}_{t+1} + t_{.025;n-2}\ S_v \qquad (6)$$

where

$$S_v = \text{the standard error of the forecast} \qquad (7)$$

$$= S_v^2 = (1-r^2)\ S_f^2$$

and

$t_{.025;n-2}$ = the value of the t distribution with n-2 degrees of freedom such that 2.5% of the area under the curve lies to the right of that value. Provides the basis for a two-sided hypothesis test at the 95% level of significance [Ref. 11].

From equations (3) and (4), the statistical accuracy of the prediction is dependent upon the size of the sample, the range of experience of the explanatory variable X, the distance between the new explanatory variable $X_{t+1}$, and the average value of all X, $\overline{X}$ [Ref. 12].

5. Presentations

For each set of variables the following presentations will be made:

a. A table of observed variables, variables in generalized difference form, and ex post forecasts. Data will be rounded to the nearest million and expressed in FY 1979 dollars.

b. An expression for the OLS regression in the form, Y = a + bX

c. An expression of the new, corrected or adjusted regression in the form $\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$

d. A table of data which will include for a range of values of the explanatory variable ($X_{t+1}$), the point estimate of the dependent variable ($\hat{Y}_{t+1}$) from equation (3), the variance of the forecast error ($S_f^2$) from equation (4), the standard error of the forecast ($S_v$) from equation (7), and the width of one side of a 95% confidence interval from equation (6).

e. A graph with procurement ($Y_t$) measured along the ordinate and RDT&E,N ($X_t$) along the abscissa, displaying the data points, the OLS regression line, the adjusted regression line, and 95% confidence bands about the adjusted regression line.

f. A graph of procurement and RDT&E measured along the ordinate versus time measured along the abscissa, displaying observed data, forecasted results (i.e. what the model would have predicted), and 95% confidence bands about the forecasted value. The width of these confidence bands is that of the "next" forecast if the explanatory variable ($X_{t+1}$) were exactly equal to the average of the previous explanatory variables ($\overline{X}$). Thus, it is as narrow as it can be and, for the purposes of presenting pictorially how well the model predicted ex post facto, presents the most rigorous test. In addition, a numerical expression of the goodness of fit over the entire time period, $R^2$, is provided.

$$R^2 = \frac{\text{Regression Sum of the Squares (RSS)}}{\text{Total Sum of the Squares (TSS)}}$$

where

TSS = The total variation of the dependent variable. The sum of the squares of the difference between the observed values of $Y_t$ and the average value of $Y_t$,

and

RSS = The explained variation of the dependent variable. The sum of the squares of the differences between the forecasted or predicted values of $Y_t$ and the average value of $Y_t$.

$R^2$ expresses that fraction of the total variance of the dependent variable which is "explained" by the explanatory variable.

# IV. THE RESULTS

The results of the analyses will now be presented as described in paragraph II.D.5. The first four analyses will match budget year RDT&E with a single year of total Navy procurement one, two, three, and four years in the future. The fifth analysis matches budget year RDT&E with the aggregate of total Navy procurement in the program years, and the remaining three analyses explore alternatives along similar four-year aggregate procurement totals, again using RDT&E as the explanatory variable.

For each set of variables, denoted by second-order headings (A,B,...,H), the following presentations will made under corresponding third-order headings: (1) A table of observed variables, variables in generalized difference form and ex post forecasts (more fully explained in paragraph III.D.5.a). (2) An expression for the OLS regression in the form

$$Y = a + bX$$

(cf., paragraph III.D.5.b). (3) An expression for the new regression in the form

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

(cf., paragraph III.D.5.c). (4) A table of data which includes for a range of values of the explanatory variable

($X_{t+1}$), the point estimate of the dependent variable ($\hat{Y}_{t+1}$), the variance of the forecast error ($S_f^2$), the standard error of the forecast ($S_v$), and the width of one side of a 95% confidence interval (cf., paragraph III.D.5.d). In addition, two figures, numbered sequentially, will be provided for each set of variables, the first showing pictorially the relationship between Procurement and RDT&E,N, and the second showing the relationship of both over time as well as the model's forecasted results (cf., paragraphs III.D.5.e and II.D.5.f).

A. PROCUREMENT IN BUDGET-YEAR-PLUS-ONE VERSUS RDT&E,N IN BUDGET YEAR

1. Observed Variables, Variables in Generalized Difference Form (r = 0.462), and Ex Post Forecast

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 62 | 3025 | ----- | 63 | 19628 | ----- | --- |
| 63 | 3394 | 1996.45 | 64 | 16449 | 7380.864 | 16998 |
| 64 | 3473 | 1904.972 | 65 | 14580 | 6980.562 | 15794 |
| 65 | 3087 | 1482.474 | 66 | 18687 | 11951.04 | 16152 |
| 66 | 3332 | 1905.806 | 67 | 19380 | 10746.606 | 16826 |
| 67 | 3961 | 2421.616 | 68 | 15271 | 6317.44 | 15655 |
| 68 | 3684 | 1854.018 | 69 | 13822 | 6766.798 | 15397 |
| 69 | 4075 | 2372.992 | 70 | 14801 | 8415.236 | 13228 |
| 70 | 4011 | 2128.35 | 71 | 13405 | 6566.938 | 14387 |
| 71 | 3718 | 1864.918 | 72 | 14510 | 8316.89 | 14503 |
| 72 | 3865 | 2147.284 | 73 | 13744 | 7040.38 | 14198 |
| 73 | 3841 | 2055.37 | 74 | 12307 | 5957.272 | 14110 |
| 74 | 3755 | 1980.458 | 75 | 10879 | 5193.166 | 13662 |
| 75 | 3893 | 2158.19 | 76 | 12332 | 7305.902 | 13579 |
| 76 | 3991 | 2192.434 | 77 | 14787 | 9089.616 | 13061 |
| 77 | 4297 | 2453.158 | 78 | 15122 | 8290.406 | 13442 |
| 78 | 4266 | 2280.786 | 79 | 13919 | 6932.636 | 14090 |

2. OLS Regression: $Y = 31195.8483 - 4.3461\ X$

3. Regression Line Adjusted for Serial Correlation:

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_t+1 - brX_t$$

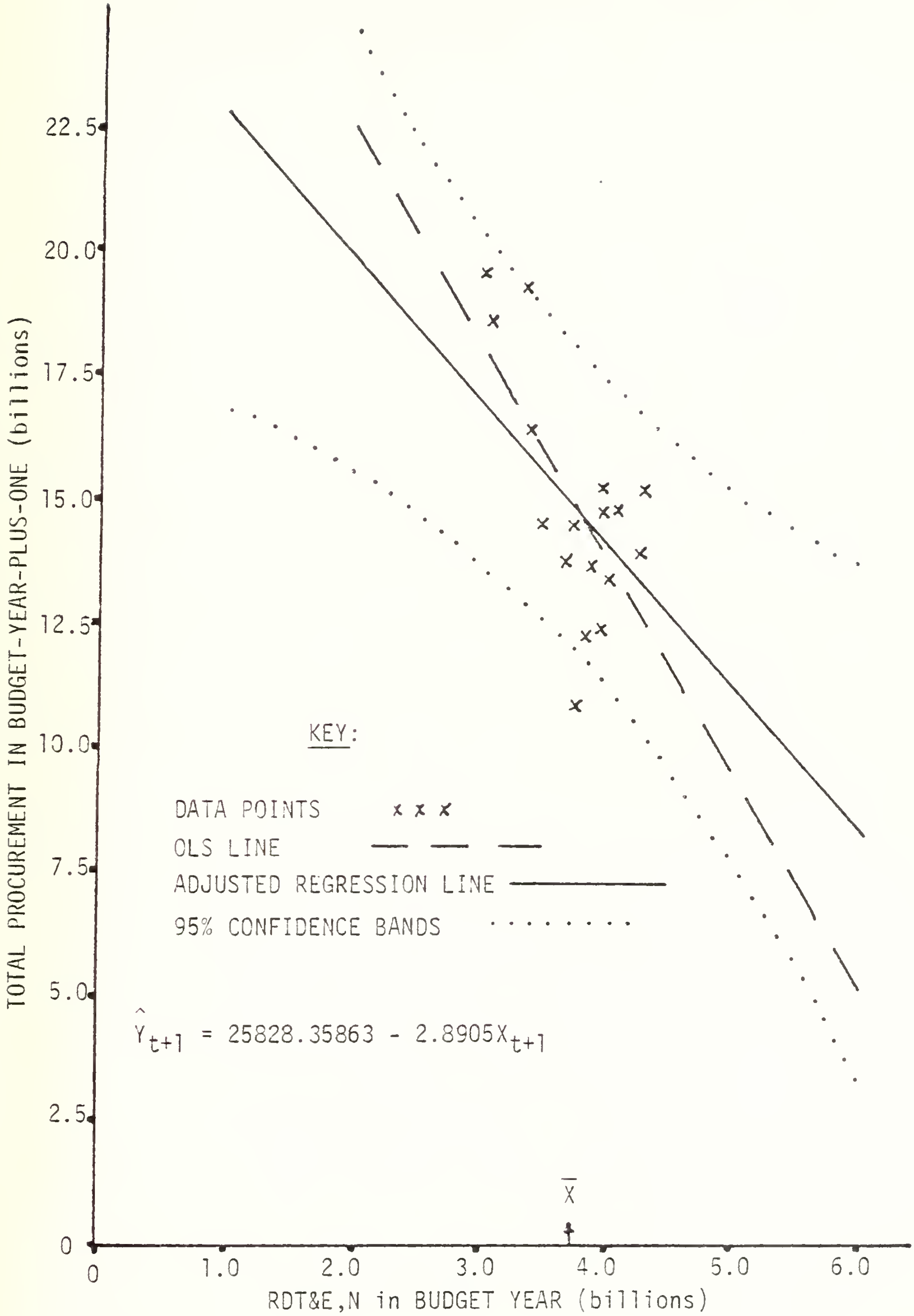
$$\hat{Y}_{t+1} = (.462)(13919) + 13700.9173 - 2.8905X_{t+1} + (2.8905)(.462)(4266)$$

$$\hat{Y}_{t+1} = 25828.35863 - 2.8905\ X_{t+1}$$

4. Data Table:

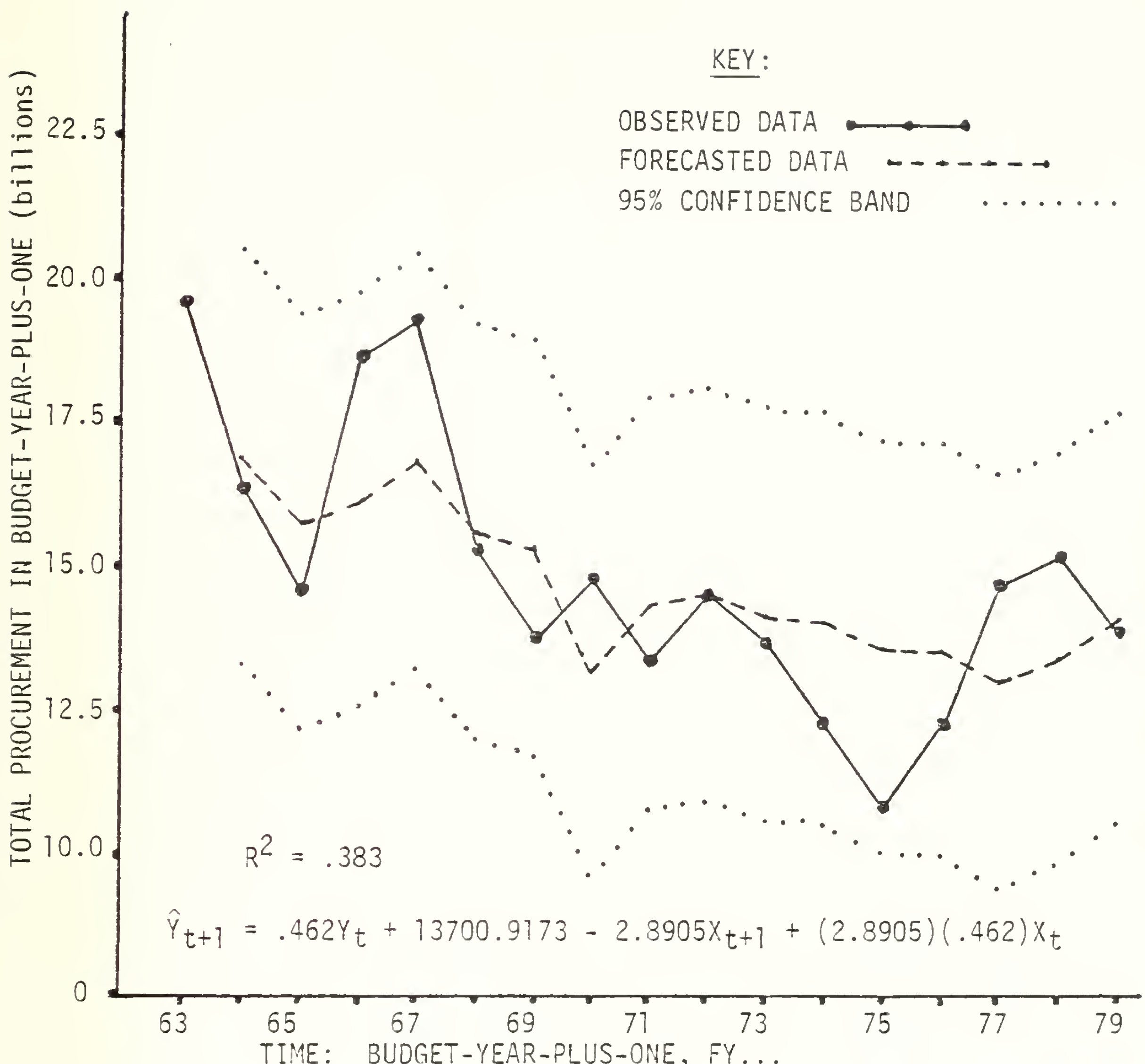
| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 22938 | 15565656.6 | 3499 | 7456 |
| 2000 | 20047 | 8504593.073 | 2586 | 5512 |
| 3000 | 17157 | 4589076.808 | 1900 | 4049 |
| 3745 | 15003 | 3716012.22 | 1710 | 3643 |
| 4000 | 14266 | 3818107.809 | 1733 | 3693 |
| 5000 | 11376 | 6191686.073 | 2207 | 4703 |
| 6000 | 8485 | 11709811.60 | 3035 | 6467 |

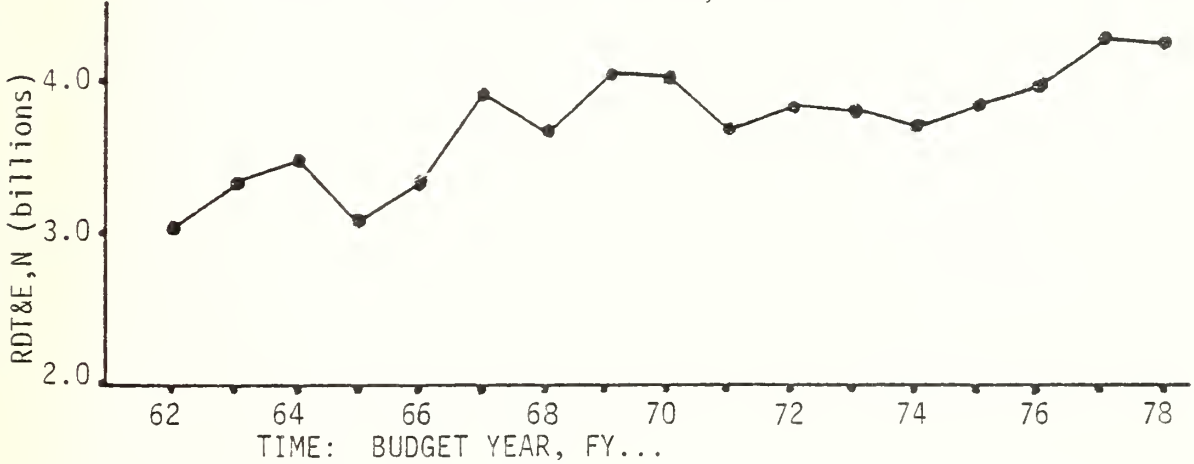
FIGURE 1



TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-ONE (billions)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
0
1.0
2.0
3.0
4.0
5.0
6.0
$\overline{X}$
RDT&E,N in BUDGET YEAR (billions)
KEY:
DATA POINTS x x x
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS
$\hat{Y}_{t+1} = 25828.35863 - 2.8905X_{t+1}$

FIGURE 2


KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BAND
TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-ONE (billions)
22.5
20.0
17.5
15.0
12.5
10.0
0
$R^2$ = .383
$\hat{Y}_{t+1} = .462Y_t + 13700.9173 - 2.8905X_{t+1} + (2.8905)(.462)X_t$
63
65
67
69
71
73
75
77
79
TIME: BUDGET-YEAR-PLUS-ONE, FY...


RDT&E,N (billions)
4.0
3.0
2.0
62
64
66
68
70
72
74
76
78
TIME: BUDGET YEAR, FY...

B. PROCUREMENT IN BUDGET-YEAR-PLUS-TWO VS. RDT&E,N IN BUDGET YEAR

1. Observer Variables, Variables in Generalized Difference Form (r=.446), and Ex Post Forecast

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 62 | 3025 | ----- | 64 | 16449 | ----- | ---- |
| 63 | 3394 | 2044.85 | 65 | 14580 | 7243.746 | 15552 |
| 64 | 3473 | 1959.276 | 66 | 18687 | 12184.32 | 15010 |
| 65 | 3087 | 1538.042 | 67 | 19380 | 11045.598 | 18278 |
| 66 | 3332 | 1955.198 | 68 | 15271 | 6627.52 | 17165 |
| 67 | 3961 | 2474.928 | 69 | 13822 | 7011.134 | 13560 |
| 68 | 3684 | 1917.294 | 70 | 14801 | 8636.388 | 14814 |
| 69 | 4075 | 2431.936 | 71 | 13405 | 6803.754 | 13497 |
| 70 | 4011 | 2193.55 | 72 | 14510 | 8531.37 | 13687 |
| 71 | 3718 | 1929.094 | 73 | 13744 | 7272.54 | 15081 |
| 72 | 3865 | 2206.772 | 74 | 12307 | 6177.176 | 13793 |
| 73 | 3841 | 2117.21 | 75 | 10879 | 5390.078 | 13458 |
| 74 | 3755 | 2041.914 | 76 | 12332 | 7479.966 | 13078 |
| 75 | 3893 | 2218.27 | 77 | 14787 | 9286.928 | 13124 |
| 76 | 3991 | 2254.722 | 78 | 15122 | 8526.998 | 14095 |
| 77 | 4297 | 2517.014 | 79 | 13919 | 7174.588 | 13350 |

2. OLS Regression: $Y = 28558.594 - 3.7531\ X$

3. Regression Line Adjusted for Serial Correlation:

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

$$\hat{Y}_{t+1} = (.446)(13919) + 15188.2496 - 3.4098X_{t+1} + (3.4098)(.446)(4297)$$

$$\hat{Y}_{t+1} = 27930.87573 - 3.4098X_{t+1}$$

4. Data Table:

| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 24521 | 15188245.69 | 3488 | 7482 |
| 2000 | 21111 | 8056099.446 | 2540 | 5449 |
| 3000 | 17701 | 4147349.016 | 1823 | 3910 |
| 3713 | 15270 | 3328866.905 | 1633 | 3503 |
| 4000 | 14292 | 3461967.396 | 1665 | 3571 |
| 5000 | 10882 | 5999981.585 | 2192 | 4702 |
| 6000 | 7472 | 11761382.58 | 3070 | 6585 |

FIGURE 3

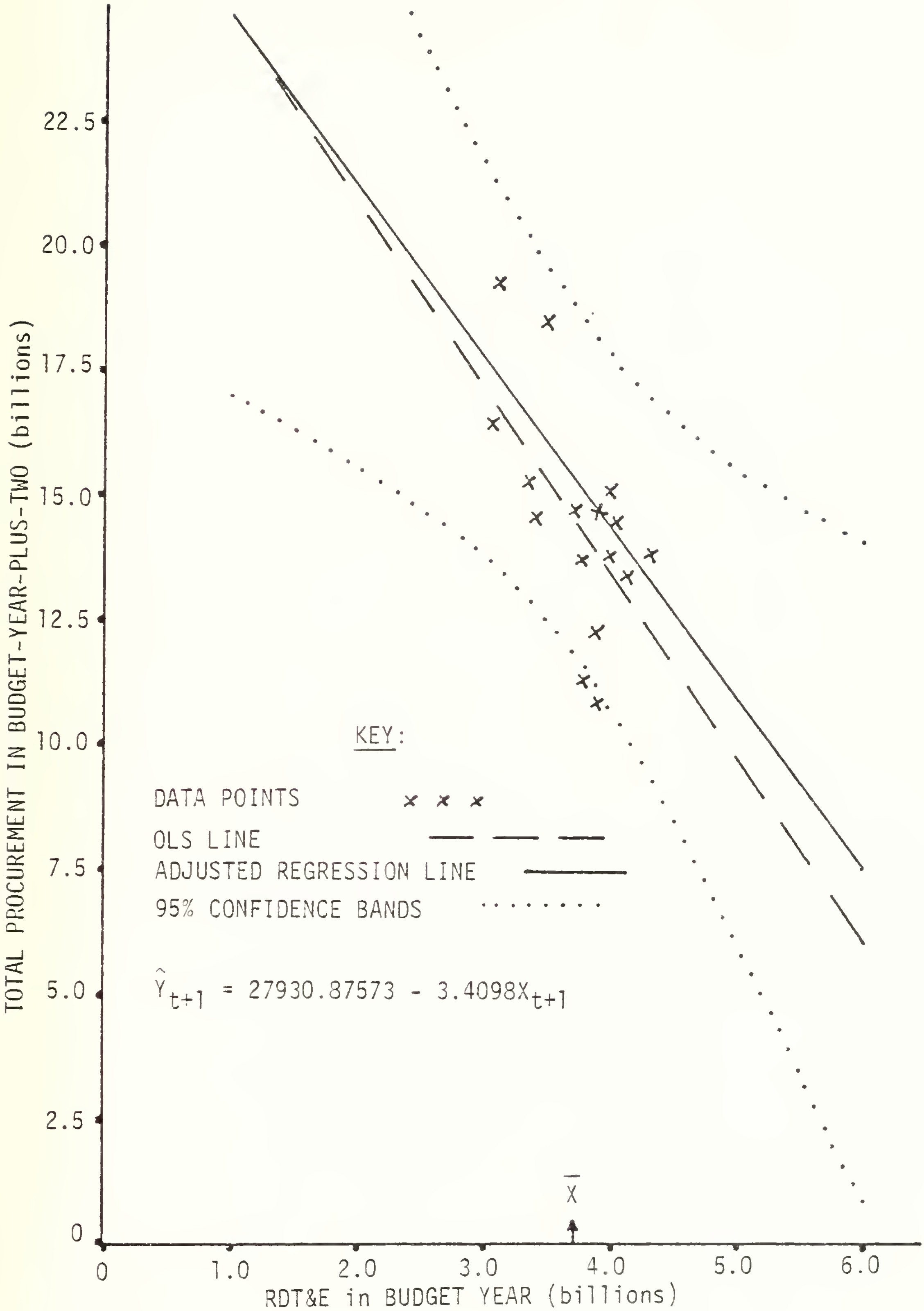
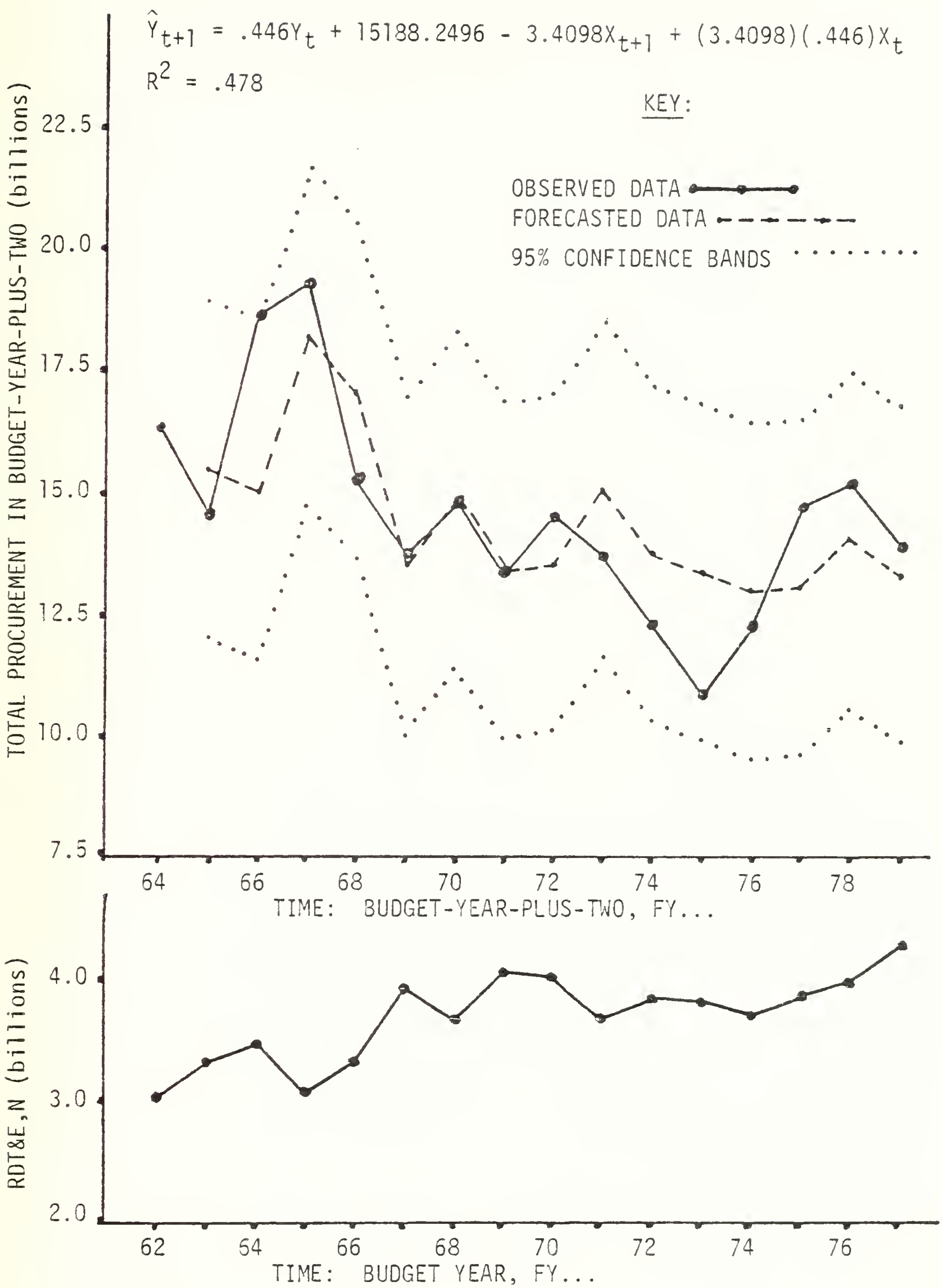

TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-TWO (billions)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
KEY:
DATA POINTS
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS
$\hat{Y}_{t+1} = 27930.87573 - 3.4098X_{t+1}$
$\bar{X}$
0
1.0
2.0
3.0
4.0
5.0
6.0
RDT&E in BUDGET YEAR (billions)

FIGURE 4



$\hat{Y}_{t+1} = .446Y_t + 15188.2496 - 3.4098X_{t+1} + (3.4098)(.446)X_t$
$R^2 = .478$
KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BANDS
TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-TWO (billions)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
64
66
68
70
72
74
76
78
TIME: BUDGET-YEAR-PLUS-TWO, FY...
RDT&E,N (billions)
4.0
3.0
2.0
62
64
66
68
70
72
74
76
TIME: BUDGET YEAR, FY...

C. PROCUREMENT IN BUDGET-YEAR-PLUS-THREE VS. RDT&E,N IN BUDGET YEAR.

1. Observed Variables, Variables in Generalized Difference Form ($r$=.823), and Ex Post Forecast.

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 62 | 3025 | ----- | 65 | 14580 | ----- | ---- |
| 63 | 3394 | 904.425 | 66 | 18687 | 6687.66 | 15264 |
| 64 | 3374 | 679.738 | 67 | 19380 | 4000.599 | 16001 |
| 65 | 3087 | 228.721 | 68 | 15271 | -678.74 | 16580 |
| 66 | 3332 | 791.399 | 69 | 13822 | 1253.967 | 15392 |
| 67 | 3961 | 1218.764 | 70 | 14801 | 3425.494 | 15866 |
| 68 | 3684 | 424.097 | 71 | 13405 | 1223.777 | 13573 |
| 69 | 4075 | 1043.068 | 72 | 14510 | 3477.685 | 14838 |
| 70 | 4011 | 657.275 | 73 | 13744 | 1802.27 | 14243 |
| 71 | 3718 | 416.947 | 74 | 12307 | 995.688 | 12676 |
| 72 | 3865 | 805.086 | 75 | 10870 | 750.339 | 13006 |
| 73 | 3841 | 660.105 | 76 | 12332 | 3378.583 | 11266 |
| 74 | 3755 | 593.857 | 77 | 14787 | 4637.764 | 12203 |
| 75 | 3893 | 802.635 | 78 | 15122 | 2952.299 | 15037 |
| 76 | 3991 | 787.061 | 79 | 13919 | 1473.594 | 15253 |

2. OLS Regression: $Y = 23284.4885 - 2.3904\ X$

3. Regression Line Adjusted for Serial Correlation:

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

$$\hat{Y}_{t+1} = (.823)(13919) - 261.2879 + 3.8988X_{t+1} - (3.8988)(.823)(3991)$$

$$\hat{Y}_{t+1} = -1611.922088 + 3.8988\ X_{t+1}$$

4. Data Table:

| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 2287 | 25236249.15 | 2854 | 6164 |
| 2000 | 6186 | 12816433.19 | 2034 | 4393 |
| 3000 | 10084 | 6110380.133 | 1404 | 3032 |
| 3674 | 12712 | 4813815.148 | 1246 | 2692 |
| 4000 | 13983 | 5118089.976 | 1285 | 2776 |
| 5000 | 17882 | 9839562.719 | 1782 | 3849 |
| 6000 | 21781 | 20274798.36 | 2558 | 5525 |

FIGURE 5

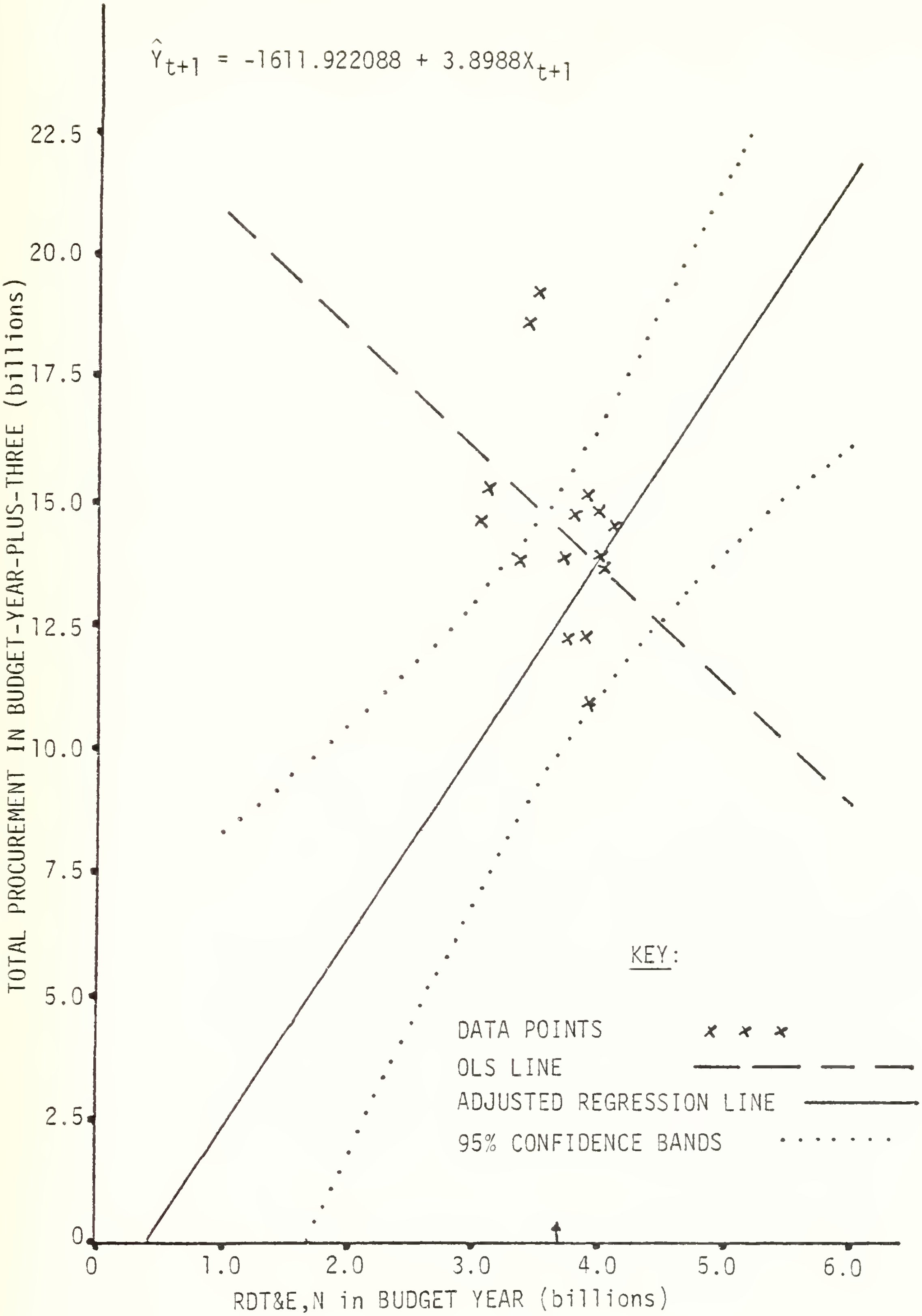
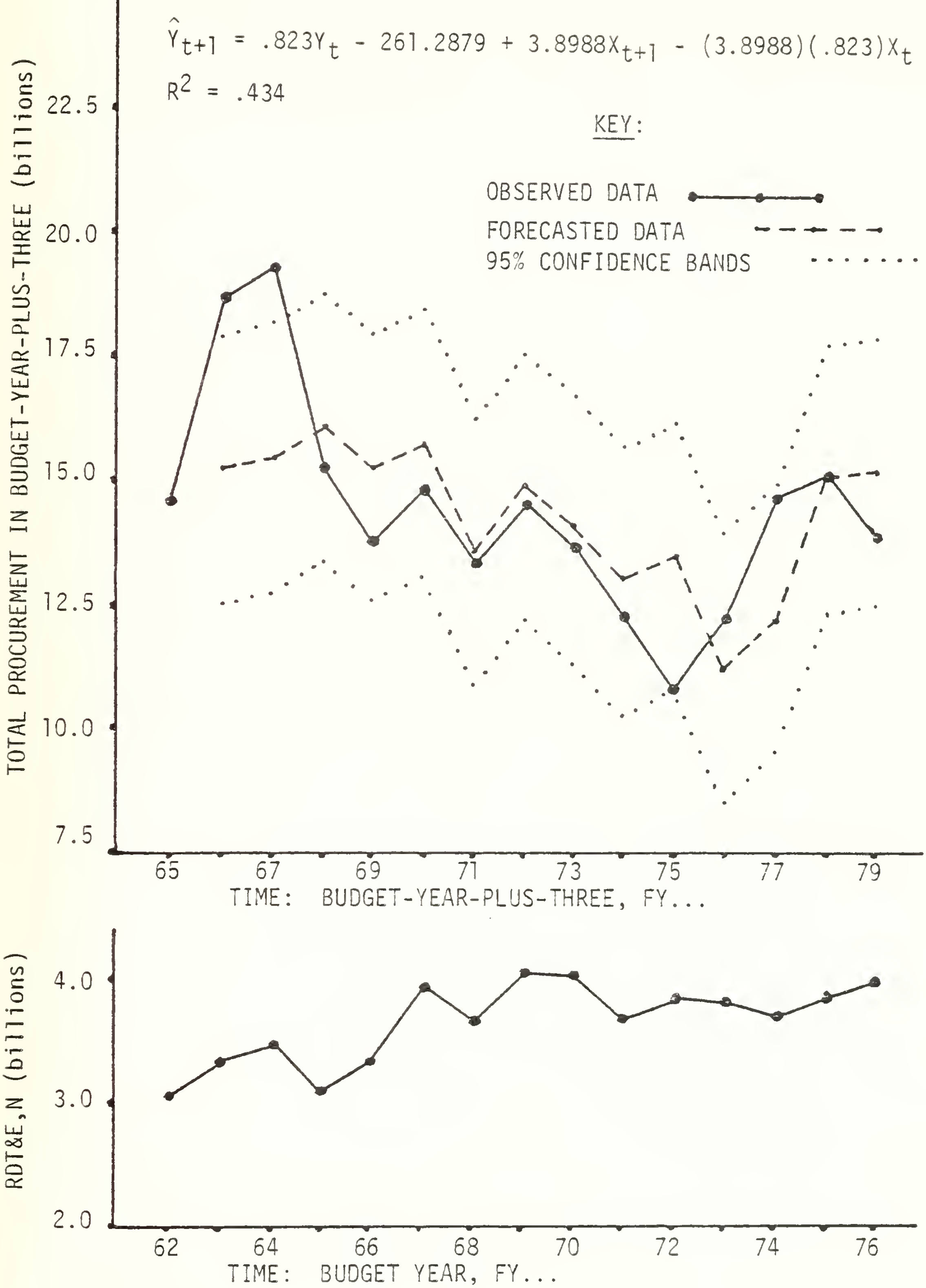

$\hat{Y}_{t+1} = -1611.922088 + 3.8988X_{t+1}$
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-THREE (billions)
0
1.0
2.0
3.0
4.0
5.0
6.0
RDT&E,N in BUDGET YEAR (billions)
KEY:
DATA POINTS
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS

FIGURE 6


$\hat{Y}_{t+1} = .823Y_t - 261.2879 + 3.8988X_{t+1} - (3.8988)(.823)X_t$
$R^2 = .434$
KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BANDS
TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-THREE (billions)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
65
67
69
71
73
75
77
79
TIME: BUDGET-YEAR-PLUS-THREE, FY...
RDT&E,N (billions)
4.0
3.0
2.0
62
64
66
68
70
72
74
76
TIME: BUDGET YEAR, FY...

D. PROCUREMENT IN BUDGET-YEAR-PLUS-FOUR VS. RDT&E,N IN BUDGET YEAR:

1. Observed Variables, Variables in Generalized Difference Form (r=.600), and Ex Post Forecast:

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 62 | 3025 | ---- | 66 | 18687 | ---- | ---- |
| 63 | 3394 | 1579 | 67 | 19380 | 8167.8 | 16676 |
| 64 | 3473 | 1436.6 | 68 | 15271 | 3643.0 | 17058 |
| 65 | 3087 | 1003.2 | 69 | 13822 | 4659.4 | 14490 |
| 66 | 3332 | 1479.8 | 70 | 14801 | 6507.8 | 13734 |
| 67 | 3961 | 1961.8 | 71 | 13405 | 4524.4 | 14436 |
| 68 | 3684 | 1307.4 | 72 | 14510 | 6467 | 13443 |
| 69 | 4075 | 1864.6 | 73 | 13744 | 5038 | 14238 |
| 70 | 4011 | 1566 | 74 | 12307 | 4060.6 | 13708 |
| 71 | 3718 | 1311.4 | 75 | 10879 | 3494.8 | 12785 |
| 72 | 3865 | 1634.2 | 76 | 12332 | 5804.6 | 12005 |
| 73 | 3841 | 1522 | 77 | 14787 | 7387.8 | 12850 |
| 74 | 3755 | 1450.4 | 78 | 15122 | 6249.8 | 14305 |
| 75 | 3893 | 1640 | 79 | 13919 | 4845.8 | 14552 |

2. OLS Regression: $Y = 29141.2369 - 4.0109X$

3. Regression Line Adjusted for Serial Correlation:

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

$$\hat{Y}_{t+1} = (.600)(13919) + 5089.0391 + .2376X_{t+1} - (.2376)(.600)(3893)$$

$$\hat{Y}_{t+1} = 12885.45302 + .2376\ X_{t+1}$$

4. Data Table:

| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 13123 | 21442577.92 | 3704 | 8072 |
| 2000 | 13361 | 10722192.65 | 2620 | 5708 |
| 3000 | 13598 | 4985714.989 | 1786 | 3892 |
| 3651 | 13753 | 3929622.474 | 1586 | 3456 |
| 4000 | 13836 | 4233144.939 | 1646 | 3687 |
| 5000 | 14073 | 8464482.5 | 2328 | 5072 |
| 6000 | 14311 | 17679727.67 | 3364 | 7330 |

FIGURE 7

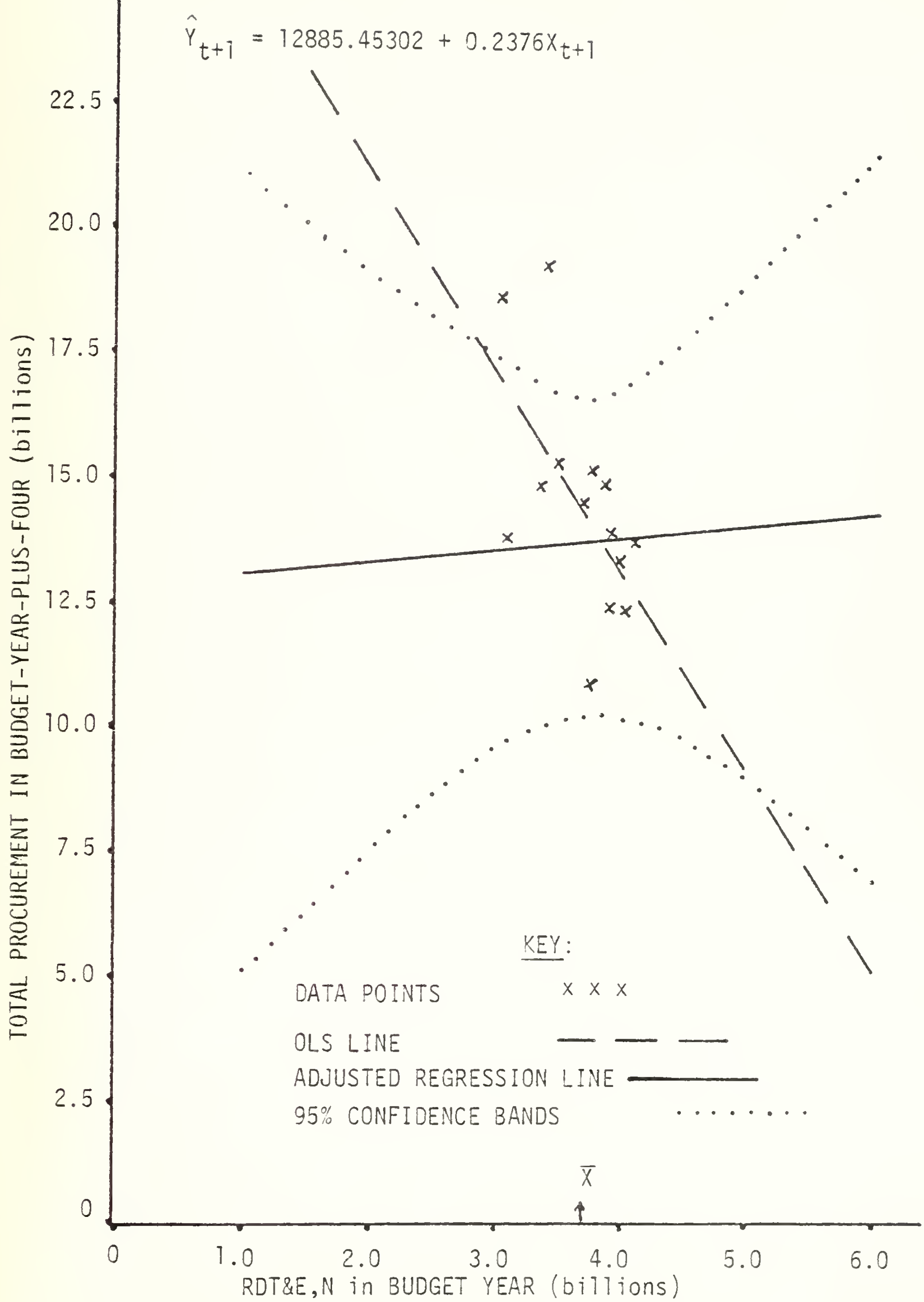
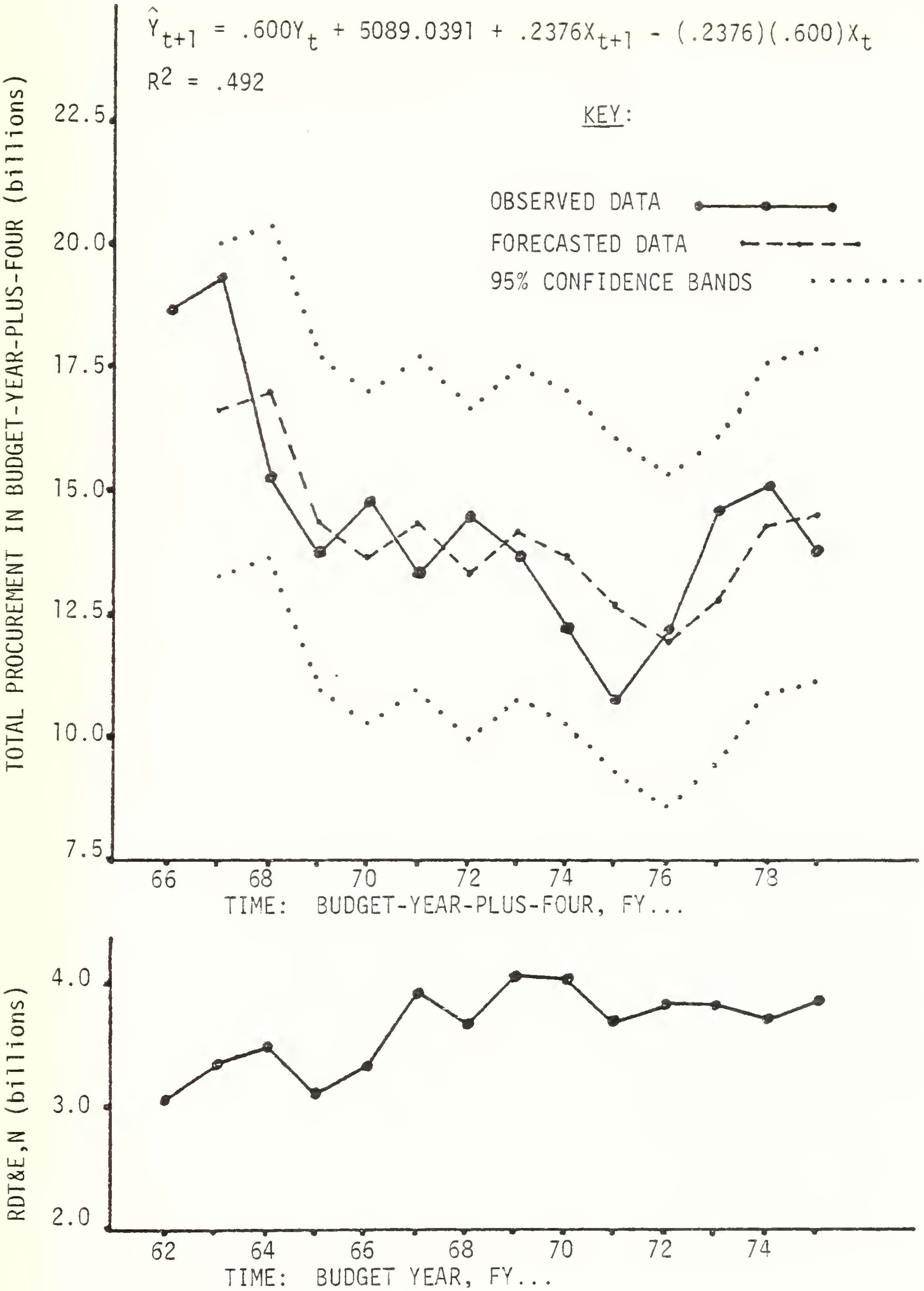

$\hat{Y}_{t+1} = 12885.45302 + 0.2376X_{t+1}$
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0
TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-FOUR (billions)
KEY:
DATA POINTS x x x
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS
$\overline{X}$
0
1.0
2.0
3.0
4.0
5.0
6.0
RDT&E,N in BUDGET YEAR (billions)

FIGURE 8



$\hat{Y}_{t+1} = .600Y_t + 5089.0391 + .2376X_{t+1} - (.2376)(.600)X_t$
$R^2 = .492$
KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BANDS
TOTAL PROCUREMENT IN BUDGET-YEAR-PLUS-FOUR (billions)
22.5
20.0
17.5
15.0
12.5
10.0
7.5
66
68
70
72
74
76
78
TIME: BUDGET-YEAR-PLUS-FOUR, FY...
RDT&E,N (billions)
4.0
3.0
2.0
62
64
66
68
70
72
74
TIME: BUDGET YEAR, FY...

E. TOTAL PROCUREMENT IN PROGRAM YEARS VS. RDT&E,N IN BUDGET YEAR

1. Observed Variables, Variables in Generalized Difference Form (r=.863), and Ex Post Forecast.

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 62 | 3025 | ---- | 63-66 | 69344 | ------ | ---- |
| 63 | 3394 | 783.425 | 64-67 | 69100 | 9256.128 | 66403 |
| 64 | 3473 | 543.978 | 65-68 | 67921 | 8287.7 | 66729 |
| 65 | 3087 | 89.801 | 66-69 | 67164 | 8548.177 | 66732 |
| 66 | 3332 | 667.919 | 67-70 | 63277 | 5314.468 | 64780 |
| 67 | 3961 | 1085.484 | 68-71 | 57302 | 2693.949 | 60489 |
| 68 | 3684 | 265.657 | 69-72 | 56541 | 7089.374 | 57173 |
| 69 | 4075 | 895.708 | 70-73 | 56463 | 7668.117 | 55101 |
| 70 | 4011 | 494.275 | 71-74 | 53969 | 5341.431 | 55935 |
| 71 | 3718 | 256.507 | 72-75 | 51443 | 4867.753 | 54317 |
| 72 | 3865 | 656.366 | 73-76 | 49266 | 4870.691 | 51239 |
| 73 | 3841 | 505.505 | 74-77 | 50308 | 7791.442 | 49699 |
| 74 | 3755 | 440.217 | 75-78 | 53123 | 9707.196 | 50745 |
| 75 | 3893 | 652.435 | 76-79 | 56163 | 10317.851 | 52698 |

2. OLS Regression: $Y = 122325.6933 - 17.4351\ X$

3. Regression Line Adjusted for Serial Correlation

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

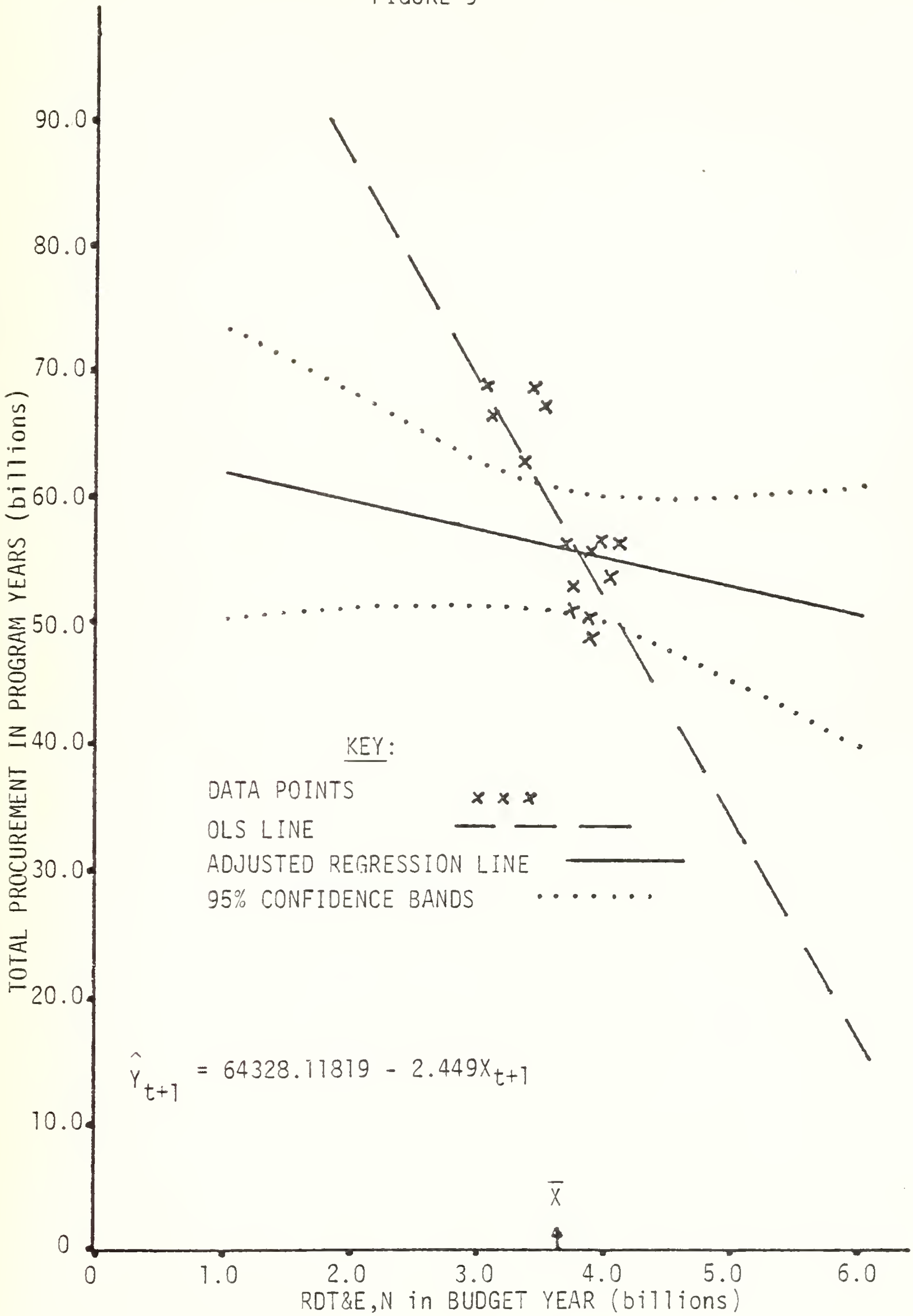
$$\hat{Y}_{t+1} = (.863)(56163) + 8317.3507 - 2.2449X_{t+1} + (2.2449)(.863)(3893)$$

$$\hat{Y}_{t+1} = 64328.11819 - 2.2449\ X_{t+1}$$

4. Data Table

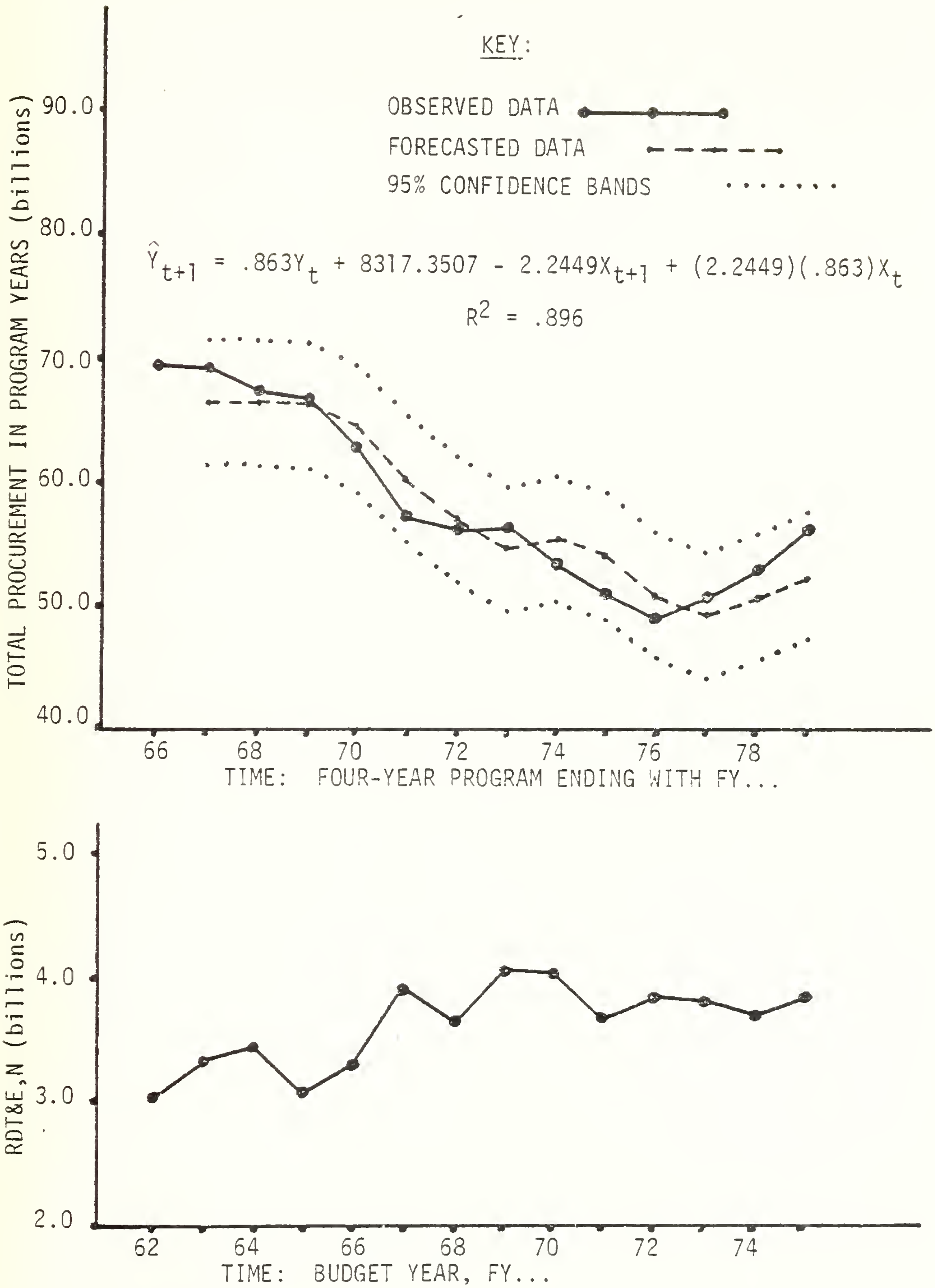
| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 62083 | 114633753.4 | 5409 | 11786 |
| 2000 | 59838 | 57321707.88 | 3825 | 8335 |
| 3000 | 57593 | 26654035 | 2608 | 5683 |
| 3651 | 56132 | 21008079.12 | 2316 | 5046 |
| 4000 | 55349 | 22630734.74 | 2403 | 5237 |
| 5000 | 53104 | 45251807.08 | 3398 | 7405 |
| 6000 | 50859 | 94517252.04 | 4912 | 10702 |

FIGURE 9



90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
TOTAL PROCUREMENT IN PROGRAM YEARS (billions)
KEY:
DATA POINTS
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS
$\hat{Y}_{t+1} = 64328.11819 - 2.449X_{t+1}$
$\overline{X}$
0
1.0
2.0
3.0
4.0
5.0
6.0
RDT&E,N in BUDGET YEAR (billions)

FIGURE 10


KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BANDS
$\hat{Y}_{t+1} = .863Y_t + 8317.3507 - 2.2449X_{t+1} + (2.2449)(.863)X_t$
$R^2 = .896$
TOTAL PROCUREMENT IN PROGRAM YEARS (billions)
90.0
80.0
70.0
60.0
50.0
40.0
66
68
70
72
74
76
78
TIME: FOUR-YEAR PROGRAM ENDING WITH FY...
RDT&E,N (billions)
5.0
4.0
3.0
2.0
62
64
66
68
70
72
74
TIME: BUDGET YEAR, FY...

F. PAMN (WPN&APN) IN PROGRAM YEARS VS RDT&E,N IN BUDGET YEAR

1. Observed Variables, Variables in Generalized Difference Form (r=.821), and Ex Post Forecast

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 62 | 3025 | ---- | 63-66 | 24781 | ----- | ---- |
| 63 | 3394 | 910.475 | 64-67 | 25610 | 5264.799 | 24046 |
| 64 | 3373 | 686.526 | 65-68 | 26062 | 5036.19 | 25004 |
| 65 | 3087 | 235.667 | 66-69 | 26323 | 4926.098 | 25932 |
| 66 | 3332 | 797.573 | 67-70 | 24090 | 2478.817 | 25452 |
| 67 | 3961 | 1225.428 | 68-71 | 22157 | 2379.11 | 23089 |
| 68 | 3684 | 432.019 | 69-72 | 22188 | 3997.103 | 22484 |
| 69 | 4075 | 1050.436 | 70-73 | 21952 | 3735.652 | 21744 |
| 70 | 4011 | 665.425 | 71-74 | 22215 | 4192.408 | 22027 |
| 71 | 3718 | 424.969 | 72-75 | 21219 | 2980.485 | 22417 |
| 72 | 3865 | 812.522 | 73-76 | 19918 | 2497.201 | 21243 |
| 73 | 3841 | 667.835 | 74-77 | 20034 | 3681.322 | 20354 |
| 74 | 3755 | 601.539 | 75-78 | 21093 | 4645.086 | 20531 |
| 75 | 3893 | 810.145 | 76-79 | 22727 | 5409.647 | 21142 |

2. OLS Regression: $Y = 40680.8239 - 4.8746\ X$

3. Regression Line Adjusted for Serial Correlation

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

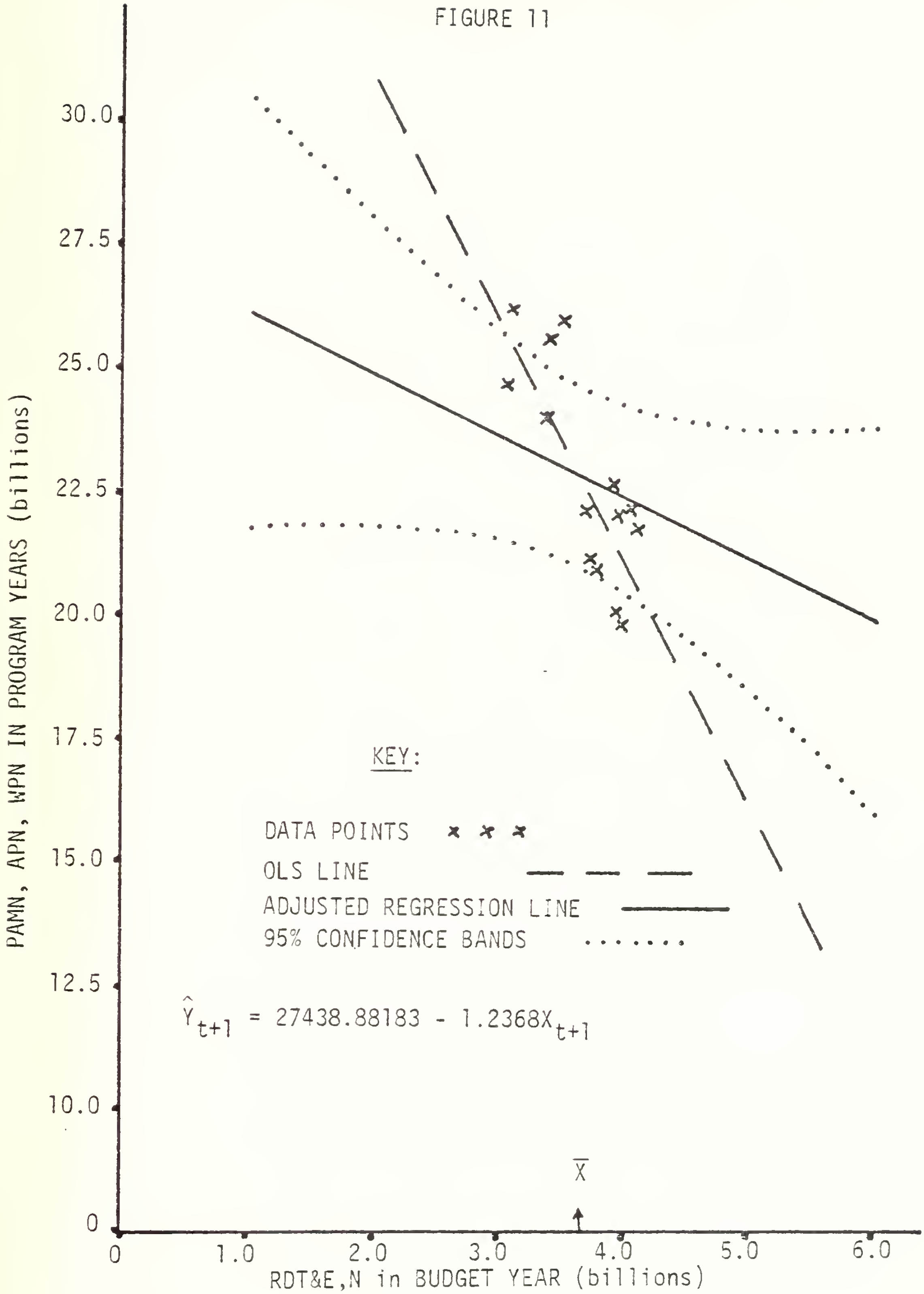
$$\hat{Y}_{t+1} = (.821)(22727) \_ 4827.0128 - (1.2368)(X_{t+1})$$
$$+ (1.2368)(.821)(3893)$$

$$\hat{Y}_{t+1} = 27438.88183 - 1.2368\ X_{t+1}$$

4. Data Table

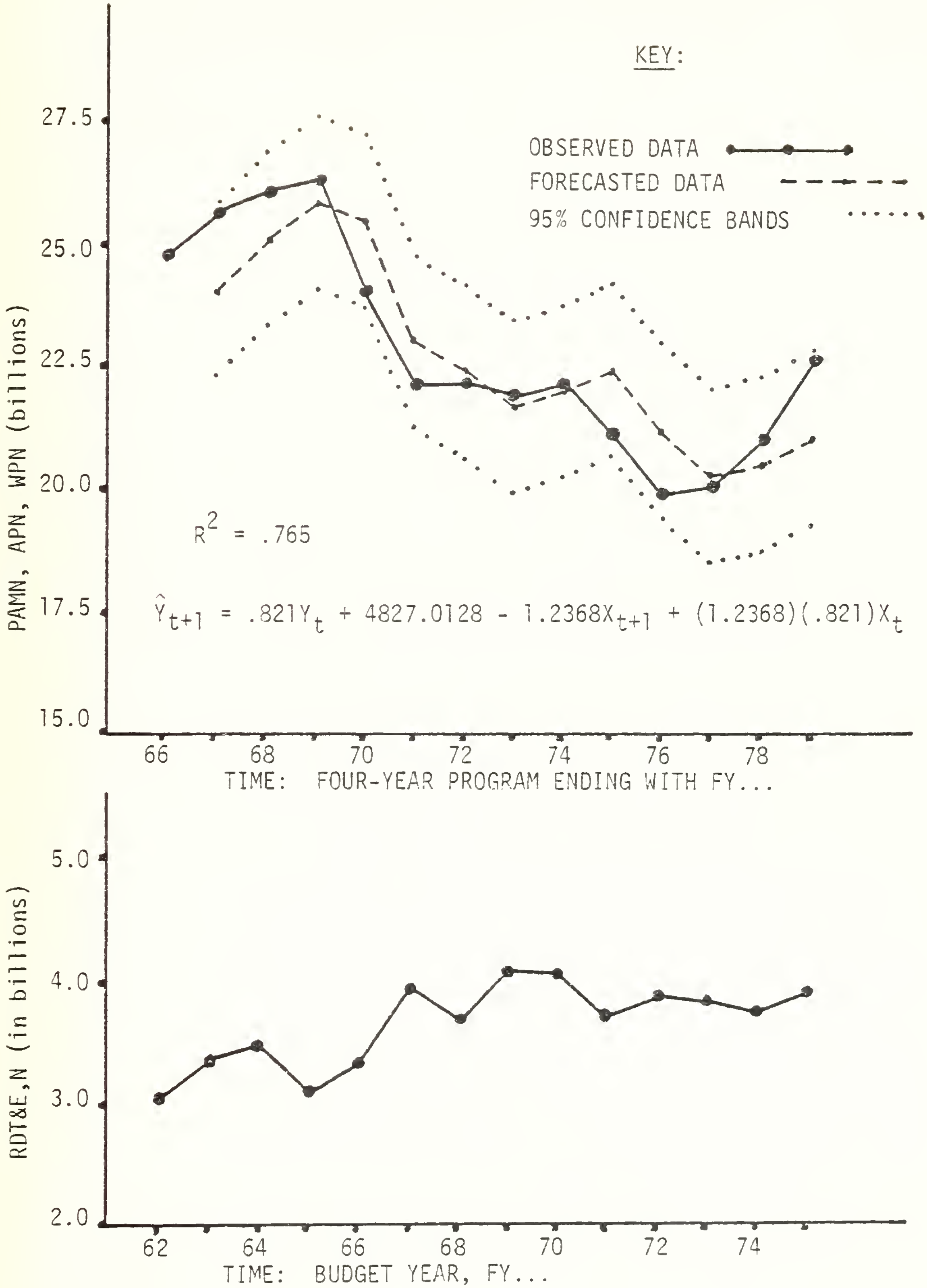
| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 26202 | 12029394.1 | 1980 | 4315 |
| 2000 | 24965 | 6015204.024 | 1400 | 3051 |
| 3000 | 23728 | 2797011.194 | 955 | 2081 |
| 2651 | 22923 | 2204537.98 | 848 | 1847 |
| 4000 | 22492 | 2374815.61 | 880 | 1917 |
| 5000 | 21255 | 4748617.272 | 1244 | 2711 |
| 6000 | 20018 | 9918416.18 | 1798 | 3918 |

FIGURE 11



30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
0
PAMN, APN, WPN IN PROGRAM YEARS (billions)
KEY:
DATA POINTS
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS
$\hat{Y}_{t+1} = 27438.88183 - 1.2368X_{t+1}$
$\overline{X}$
0
1.0
2.0
3.0
4.0
5.0
6.0
RDT&E,N in BUDGET YEAR (billions)

FIGURE 12


KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BANDS
27.5
25.0
22.5
20.0
17.5
15.0
PAMN, APN, WPN (billions)
$R^2$ = .765
$\hat{Y}_{t+1} = .821Y_t + 4827.0128 - 1.2368X_{t+1} + (1.2368)(.821)X_t$
66
68
70
72
74
76
78
TIME: FOUR-YEAR PROGRAM ENDING WITH FY...
5.0
4.0
3.0
2.0
RDT&E,N (in billions)
62
64
66
68
70
72
74
TIME: BUDGET YEAR, FY...

## G. TOTAL PROCUREMENT IN THE PROGRAM YEARS VERSUS RDT&E,N IN THE BUDGET YEAR, USING ELEVEN MOST RECENT DATA POINTS ONLY

### 1. Observed Variables, Variables in Generalized Difference Form (r=.640), and Ex Post Forecast

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 65 | 3087 | ----- | 66-69 | 67164 | ----- | ---- |
| 66 | 3332 | 1356.32 | 67-70 | 63277 | 20292.04 | 62071 |
| 67 | 3961 | 1838.52 | 68-71 | 57302 | 16804.72 | 59114 |
| 68 | 3684 | 1148.96 | 69-72 | 56541 | 19867.72 | 55966 |
| 69 | 4075 | 1717.24 | 70-73 | 56463 | 20276.76 | 54913 |
| 70 | 4011 | 1403 | 71-74 | 53969 | 17832.68 | 55176 |
| 71 | 3718 | 1150.96 | 72-75 | 51443 | 16902.84 | 53831 |
| 72 | 3865 | 1485.48 | 73-76 | 49266 | 16342.48 | 51881 |
| 73 | 3841 | 1367.4 | 74-77 | 50308 | 18777.76 | 50608 |
| 74 | 3755 | 1296.76 | 75-78 | 53123 | 20925.88 | 51343 |
| 75 | 3893 | 1489.8 | 76-79 | 56163 | 22164.28 | 52952 |

### 2. OLS Regression: $Y = 105846.7778 - 13.3253\ X$

### 3. Regression Line Adjusted for Serial Correlation:

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

$$\hat{Y}_{t+1} = (.640)(56163) + 20436.5695 - .9954X_{t+1} + (.9954)(.640)(3893)$$

$$\hat{Y}_{t+1} = 58860.94851 - .9954\ X_{t+1}$$

### 4. Data Table:

| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 57866 | 144425746.7 | 9234 | 20888 |
| 2000 | 56870 | 68126434.4 | 6342 | 14346 |
| 3000 | 55875 | 25776334.75 | 3901 | 8824 |
| 3747 | 55131 | 16292824.35 | 3101 | 7016 |
| 4000 | 54879 | 17375447.77 | 3203 | 7245 |
| 5000 | 53884 | 42923773.44 | 5034 | 11387 |
| 6000 | 52889 | 102421311.8 | 7776 | 17590 |

FIGURE 13

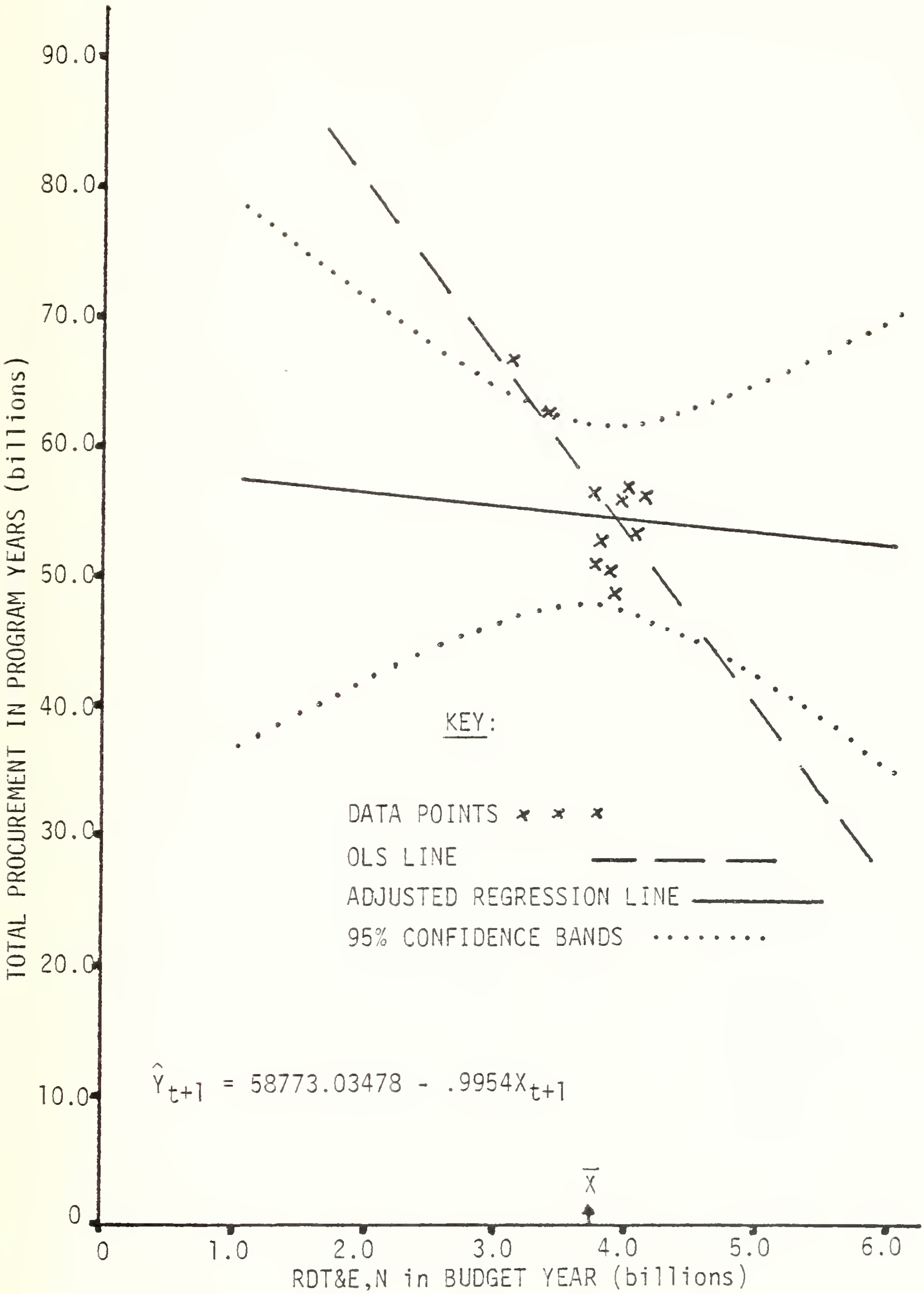
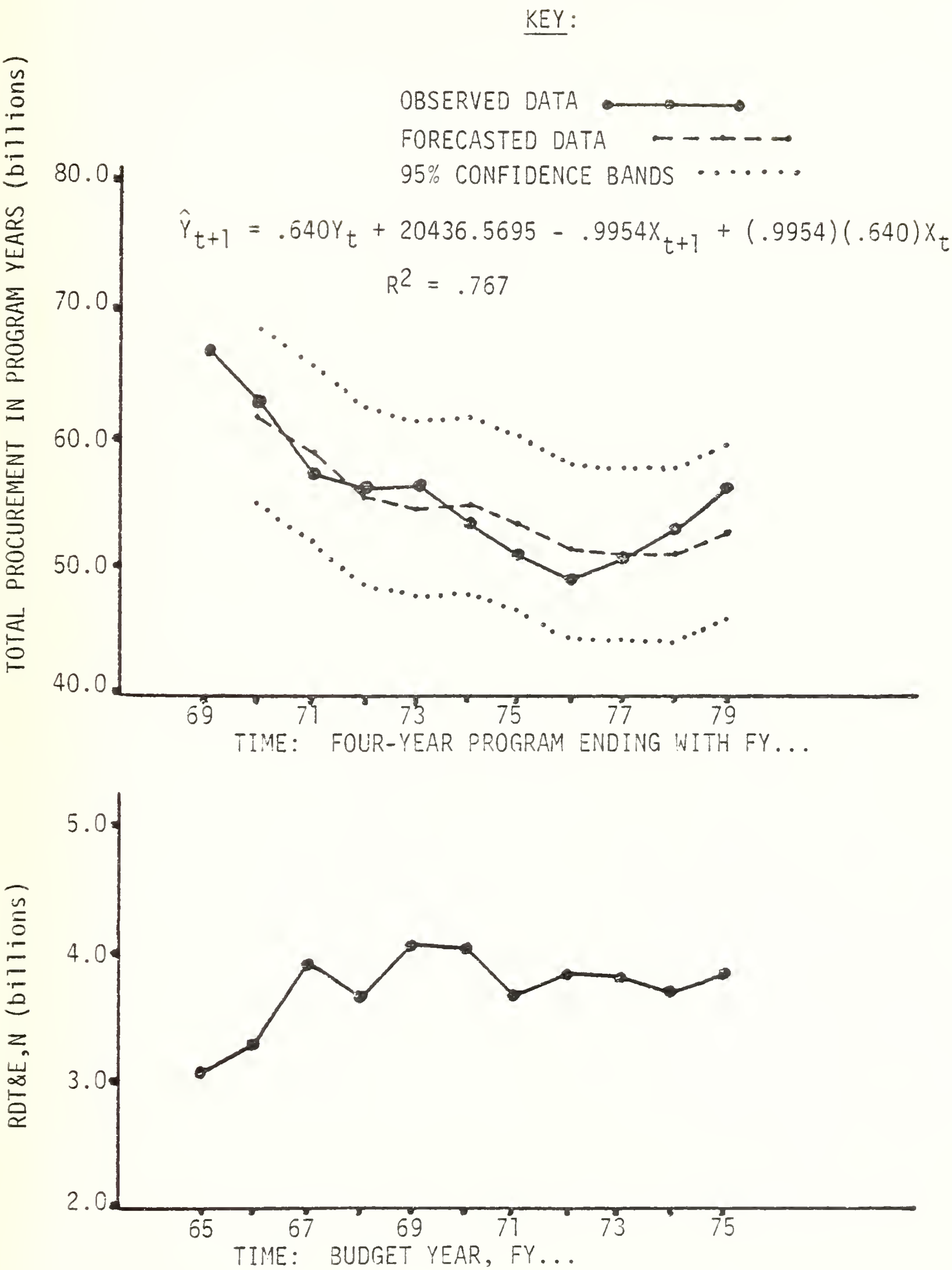

90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
TOTAL PROCUREMENT IN PROGRAM YEARS (billions)
KEY:
DATA POINTS
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS
$\hat{Y}_{t+1}$ = 58773.03478 - .9954$X_{t+1}$
$\bar{X}$
0
1.0
2.0
3.0
4.0
5.0
6.0
RDT&E,N in BUDGET YEAR (billions)

FIGURE 14


KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BANDS
$\hat{Y}_{t+1} = .640Y_t + 20436.5695 - .9954X_{t+1} + (.9954)(.640)X_t$
$R^2 = .767$
TOTAL PROCUREMENT IN PROGRAM YEARS (billions)
80.0
70.0
60.0
50.0
40.0
69
71
73
75
77
79
TIME: FOUR-YEAR PROGRAM ENDING WITH FY...
RDT&E,N (billions)
5.0
4.0
3.0
2.0
65
67
69
71
73
75
TIME: BUDGET YEAR, FY...

## H. TOTAL PROCUREMENT IN PROGRAM YEARS VERSUS RDT&E,N IN BUDGET YEAR, USING EIGHT MOST RECENT DATA POINTS ONLY

### 1. Observed Variables, Variables in Generalized Difference Form (r=.501), and Ex Post Forecast

| FY | X | X* | FY | Y | Y* | $\hat{Y}_{t+1}$ |
|---|---|---|---|---|---|---|
| 68 | 3684 | ----- | 69-72 | 56541 | ----- | ---- |
| 69 | 4075 | 2229.316 | 70-73 | 56463 | 28135.959 | 56209 |
| 70 | 4011 | 1969.425 | 71-74 | 53969 | 25681.037 | 54787 |
| 71 | 3718 | 1708.489 | 72-75 | 51443 | 24404.531 | 52149 |
| 72 | 3865 | 2002.282 | 73-76 | 49266 | 23493.057 | 52447 |
| 73 | 3841 | 1904.635 | 74-77 | 50308 | 25625.734 | 50837 |
| 74 | 3755 | 1830.659 | 75-78 | 53123 | 27918.692 | 50569 |
| 75 | 3893 | 2011.745 | 76-79 | 56163 | 29548.377 | 53339 |

### 2. OLS Regression: $Y = 35127.9406 + 4.742\ X$

### 3. Regression Line Adjusted for Serial Correlation:

$$\hat{Y}_{t+1} = rY_t + a(1-r) + bX_{t+1} - brX_t$$

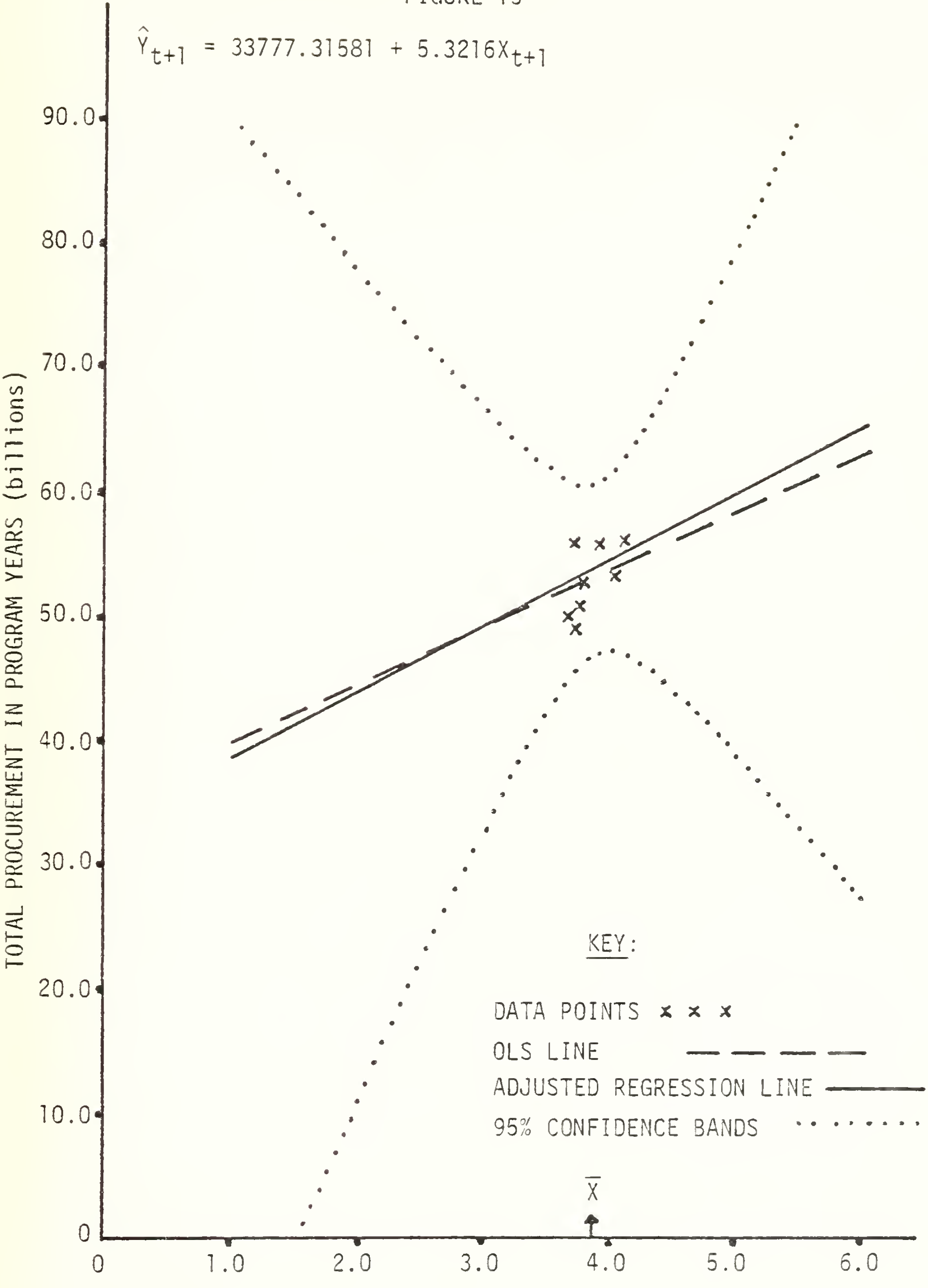
$$\hat{Y}_{t+1} = (.501)(56163) + 16018.8642 + (5.3216)X_{t+1} - (5.321)(.501)(3893$$

$$\hat{Y}_{t+1} = 33777.31581 + 5.3216\ X_{t+1}$$

### 4. Data Table:

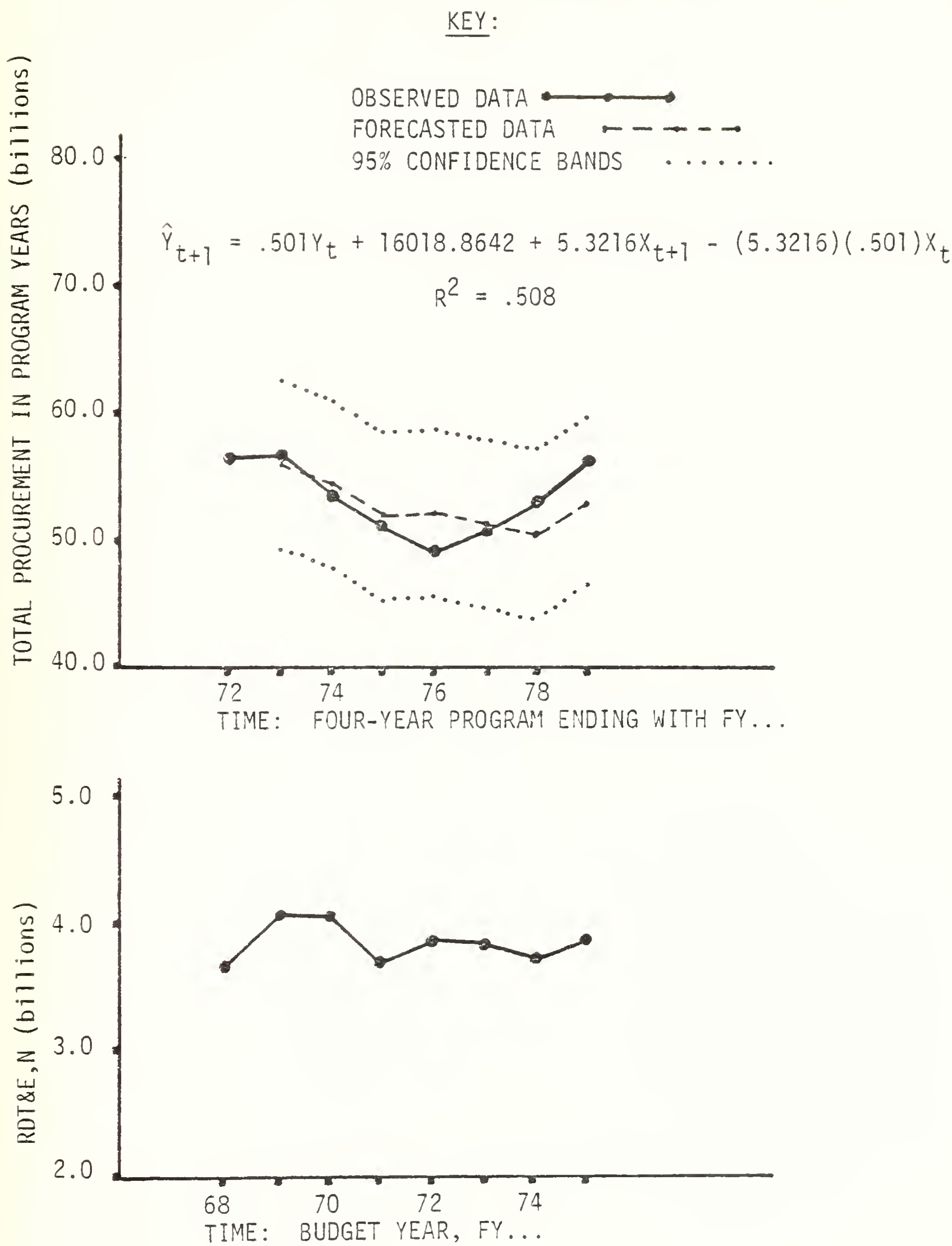
| $X_{t+1}$ | $\hat{Y}_{t+1}$ | $S_f^2$ | $S_v$ | $t_{.025;n-2}\ S_v$ |
|---|---|---|---|---|
| 1000 | 39099 | 572113395.9 | 20701 | 50654 |
| 2000 | 44421 | 247480431.1 | 13615 | 33315 |
| 3000 | 49742 | 60681226.99 | 6742 | 16497 |
| 3855 | 54292 | 10271802.58 | 2775 | 6787 |
| 4000 | 55064 | 11715783.51 | 2962 | 7249 |
| 5000 | 60385 | 100584100.7 | 8680 | 21239 |
| 6000 | 65707 | 327286178.6 | 15657 | 38312 |

FIGURE 15



$\hat{Y}_{t+1} = 33777.31581 + 5.3216X_{t+1}$
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
TOTAL PROCUREMENT IN PROGRAM YEARS (billions)
KEY:
DATA POINTS x x x
OLS LINE
ADJUSTED REGRESSION LINE
95% CONFIDENCE BANDS
$\bar{X}$
0
1.0
2.0
3.0
4.0
5.0
6.0

FIGURE 16



KEY:
OBSERVED DATA
FORECASTED DATA
95% CONFIDENCE BANDS
$\hat{Y}_{t+1} = .501Y_t + 16018.8642 + 5.3216X_{t+1} - (5.3216)(.501)X_t$
$R^2 = .508$
TOTAL PROCUREMENT IN PROGRAM YEARS (billions)
80.0
70.0
60.0
50.0
40.0
72
74
76
78
TIME: FOUR-YEAR PROGRAM ENDING WITH FY...
RDT&E,N (billions)
5.0
4.0
3.0
2.0
68
70
72
74
TIME: BUDGET YEAR, FY...

# V. THE CONCLUSIONS

## A. ANALYSIS OF REGRESSION RESULTS

Discussion of the regression results will proceed in generally the same sequence as the presentations in the previous section. Since the explanatory variable of each regression is RDT&E,N in the budget year, third-order headings which follow will refer only to the dependent variables of the regressions to be discussed.

### 1. Forecasting A Single Year's Procurement

Sections IV.A, IV.B, IV.C, and IV.D present the results of the analyses of the relationships between current RDT&E,N and a single year of total Navy procurement one, two, three, and four years in the future, respectively. The results are not very impressive. Ex post forecasts results in $R^2$ statistics of .383, .478, .434, and .492, indicating that in each case less than half of the procurement variance is "explained" by the earlier effort in RDT&E. In addition, the widths of the 95% confidence intervals about these models' point estimates are excessive. The average value of the dependent variable during the period under study is approximately $15000 million, and these models provide confidence intervals of between $5384 million and $7286 million in width (both sides). Such statistical accuracy would appear to be of little use, even at the 95% level of significance. Finally, these four regressions

appear to have very little relation to one another. The adjusted regression lines have a sharply negative slope for the first two analyses. The third year's adjusted regression line is sharply positive in slope, and the fourth year's regression provides a line of only slightly positive slope. One would expect either more consistency among these regressions or some sort of trend. Neither characteristic is in evidence, and the absence of any pattern suggests that the time period covered by the dependent variable (one year) may be too short.

2. <u>Forecasting Total Procurement in the Program Years</u>

Section IV.E displays the results of the analysis of the relationship between RDT&E,N in the budget year and total procurement in the following four years (the program years) collectively rather than individually. The ex post forecast in this case results in a $R^2$ of .896 and a 95% confidence interval of $10092 million. The $R^2$ statistic is impressive in that nearly ninety percent of the variation of the dependent variable is "explained" by the model, and the confidence interval, when compared to the average value of the dependent variable during the period studied, $58670 million, suggests that the statistical reliability of this model is superior to those produced by the single year analyses.

In spite of the apparent success of this analysis, one serious difficulty remains to be discussed: the negative slope of the adjusted regression. The OPNAV/NAVCOMPT

analysis at the very least implied that the relationship between RDT&E and future procurement was direct in nature; that the more spent now on RDT&E, the more we could expect to spend on future procurement. However, both the regression results and visual inspection of the data plotted over time (Figure 10) reveal that, on the macro level since 1962, the overall trend in total Navy procurement has been negative, while the trend in RDT&E,N has been positive. This conflict leads logically to expansion of the study in two directions, both of which will be discussed in the sections to follow.

### 3. Forecasting Aircraft and Missile (PAMN, APN, WPN) Procurement in the Program Years

In order to explore the possibility of a closer and/or more direct relationship existing between RDT&E and selected future procurements, the analysis presented in Section IV.F was conducted. Of the five current Department-of-the-Navy procurement accounts, PAMN (divided into WPN and APN since 1974) was thought to be probably the most influenced by research and development. Thus, an analysis of budget year RDT&E,N in relation to program years' collective PAMN might prove revealing.

The analysis resulted in ex post forecasts and a $R^2$ statistic of .765 and a confidence interval of $3695 million in comparison with average value of the dependent variable of $22884 million. This $R^2$ value is a little less than that of the previous analysis, but the confidence

interval is a little narrower. The indication is that this relationship is neither significantly better nor significantly worse than that matching RDT&E with total procurement. In addition, the model produced has a negative slope as did the previous regression. Thus, the expected results did not materialize. Although further attempts at factoring the data may well yield more useful results, this study explores another avenue.

4. Total Procurement in the Program Years (Reducing the Time Span)

In attempting to forecast by means of time-series data, there always exists a danger that one or more of the basic relationships among the variables involved may have changed during the period under study. Concern for this danger seems particularly appropriate with regard to this analysis (specifically, the analysis presented in Section IV.E above). The time period studied includes the Vietnam War and the extraordinary impact it must have had on specific Navy procurement actions and on the entire Navy budget in general. In addition, the very nature of changing technology provides a logical basis for arguments that earlier data (e.g. data prior to 1970 or 1973) are not valid; and visual inspection of the data tends to support this contention. Note that the last few data-point relationships seem to indicate a direct relationship between the variables: as RDT&E begins to increase, procurement increases also. See Figure 12.

In response to this, regressions were conducted using fewer data points; that is, earlier data were ignored. Sections IV.G and IV.H present analyses which use only the previous eleven and eight data pairs, respectively. The relationship is again between RDT&E,N in the budget year and total Navy procurement in the program years. The results are interesting in that the slope of the adjusted regression lines become more positive as more early data are ignored; this indicates that the supposition that the basic relationship has changed may have some validity. At the same time, however, the width and shape of the 95% confidence interval appear to have deteriorated to the point of making forecasts much less reliable. If the regression resulting from an analysis of only the last eight data points (IV.H) is the most representative of the true relationship between the variables, then there is no alternative but to accept a 95% confidence interval which is $13574 million wide at best (i.e. the next explanatory variable is equal to the average of the previous eight) and which will increase rapidly as the next explanatory variable varies from the average.

Note also that the $R^2$ statistics for the ex post forecasts conducted using only the most recent eleven and eight data points fall to .767 and .508, respectively. Although this indicates a deterioration in the goodness of fit, the amount of variation in the observed dependent

variable is also a good deal less in these regressions than in those conducted with all fourteen data points. Since the $R^2$ statistic is constructed using the squares of the deviations about the mean of the observed values of the dependent variable, it becomes more difficult, proportionately, to achieve the same $R^2$ statistic when these deviations are smaller. In other words, the relatively low $R^2$ statistics may not in these cases be cause for rejection of these regressions.

An additional interesting result occurs when comparing the predictions of the three different models for the same reasonable value of the explanatory variable, for instance $4000 million (by reasonable, we mean in the range of experience of the explanatory variable). The point estimates ($\hat{Y}_{t+1}$) produced by the fourteen-, eleven-, and eight-data-point regressions are $55349 million, $54879 million, and $55064 million, respectively. Thus, the point-estimate forecasts of the models are so close as to make their differences negligible. This is partially explained by the fact that the three models all have the most recent eight data points in common and that, by design, the more recent data have more impact on the model. Unfortunately, neither the proximity of the estimates nor the explanation for it helps to resolve the question of the true nature of the relationship between these two variables. The point estimates may be close, but each model responds quite

differently to changes in the explanatory variable. Thus, the choice of model is still crucial to the budget analyst, who is most often faced with decisions of an incremental nature.

## B. CLOSING STATEMENTS

### 1. Suggestions for Further Study

Although necessarily limited, this study may well provide a stepping-off point for further analyses. It would seem logical that the predictability of future procurement could be improved if additional explanatory variables were included in the model (e.g. GNP, total DOD budget, total Federal Budget, the unemployment rate). Lack of sufficient and relevant time-series data might in this way be overcome by pooling whatever time-series data are available with cross-section data. Of course, the methodology of multi-variable forecasting and the process of handling error disturbances are considerably more sophisticated than those used in this thesis. However, in view of the results achieved with just RDT&E, more useful and accurate predictions might be expected.

### 2. Hypothesis

With regard to the general working hypothesis proposed at the outset, it is concluded that there does exist a statistically valid predictive relationship between current Navy research and development and future Navy procurement, taking the program years as a whole. Whether

the relationships discovered in this thesis are close enough to prove useful to those who shape future Navy budgets remains open to question. Probably the most common failing of forecasting with time-series data is due to an unwarranted emphasis on the past rather than the future. Additionally, the temptation to attribute cause-and-effect qualities to purely predictive relationships is always present. The quality and usefulness of the models developed above or those which may follow should be based upon how well they predict the <u>future</u>, and, if a basic relationship <u>can</u> change, it must always be kept in mind that during the period being predicted, <u>it just might</u>!

# APPENDIX A

## THE OPNAV MEMORANDUM

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

IN REPLY REFER TO
Ser 922E21/587526
24 APR 1978

MEMORANDUM FOR SUPERINTENDENT, NAVAL POSTGRADUATE SCHOOL

Subj: Proposed Study Subject for Financial Management Students

Encl: (1) Discussion Paper

The purpose of this memorandum is to recommend a subject for study by your financial management students. I believe the study would provide results useful to those of us involved in shaping future Navy budgets and be an excellent project for a master's thesis.

The ever increasing complexity and cost of modern weapons systems is a familiar theme and we are indeed seeing more and more instances where the development of a promising new system is terminated simply because its predicted procurement costs make the system non-affordable. Nonetheless, the research and development program for the Department of Defense continues to receive increased emphasis during each year's budget deliberations. For example, the Navy's Research, Development, Test and Evaluation (RDT&E) appropriation for FY 1979 is funded at a level which provides a program real growth of approximately six percent over the FY 1978 level. In order to project the magnitude of future Navy budgets that can be anticipated as a result of the continued emphasis in research and development, my staff recently prepared an analysis of the potential procurement costs inherent in the on-going R&D programs presently funded in the RDT&E appropriation. The objective of the analysis was to develop, if possible, a prediction model that would help answer the question .... "Given a certain level of funding in research and development programs, what follow-on procurement costs can be expected?"

Although the analysis performed by my staff was intentionally limited, it did produce a rough indicator of approximately four dollars of procurement costs for every dollar of R&D, and yielded several interesting observations. For example, one program had an estimated procurement cost 33 times greater than its development cost, while other programs were noted to cost more to develop than to procure. Enclosure (1) provides additional background and a discussion of the approach used by my staff.

Subj: Proposed Study Subject for Financial Management Students (continued)

It is anticipated that appropriate research and analysis of the historical relationship between known procurement and development costs would produce numerical factors that reflect the number of procurement dollars required for every dollar of R&D. It is envisioned that the development programs would be categorized by some appropriate scheme such as functional type or mission area, e.g. -- aircraft, missiles, radar systems, sonar systems, etc., and that there would be a different factor for each category. The factors could be used as models to provide at least a rough answer to questions such as.... "If I have $10 million RDT&E funds invested in advanced surface-sonar systems development programs, how many follow-on procurement dollars will be required?" In order to keep the study effort to a manageable level and within the ability of the students to accomplish as a thesis project, I recommend that the scope be limited to purely financial analysis without regard to the cost-effectiveness of the various weapon systems.

My point of contact for this proposed area of study is Mr. Charles P. Nemfakos, Associate Director, Budget. I will welcome any comments that you or your staff may have concerning this project.

## RETURN ON INVESTMENT IN R&D PROGRAMS

o The best indicator of the amount of future procurement dollars associated with new weapons systems now in development is an analysis of those programs in the engineering development stage of the total research and development program. It is these programs that have passed a major milestone in the system acquisition decision process and are the most likely to complete development and enter production. Many of the programs in engineering development already have budget quality estimates of their procurement price tag. For those programs whose procurement cost has not yet been priced out, we can at least obtain an order-of-magnitude, ball-park estimate of procurement cost using an empirically derived prediction factor. In order to derive such a factor for FY 1979, NAVCOMPT analyzed a representative sample of programs in engineering development in FY 1979 for which budget quality estimates of total development and total procurement costs were available. From the analysis a relationship of approximately four dollars of procurement for every dollar of R&D was derived. Using this predictor, we filled in the holes in the procurement cost estimates associated with our R&D programs in engineering development.

o The NAVCOMPT analysis used a very small data base of approximately 20 programs, as shown in Tab 1. These programs were all in the FY 1979 budget and in the engineering development stage of their development program. Each of these programs had progressed to the point that budget-quality estimates of the total R&D costs and total procurement costs were available. The programs were selected in such a manner as to provide a cross-section sample of the various development technologies within the total R&D programs.

o A more accurate analysis of the relationship between procurement and development costs would, of course, require a larger data base. The minimum requirement is that both total R&D and procurement costs be known -- thus the data base is largely historical in nature. Prior-year RDT&E budgets will necessarily provide the majority of programs in the sample as these budgets will contain more programs for which actual total R&D and procurement costs are available. Current year and budget year budgets also can be analyzed as budget-quality estimates of total R&D and procurement costs can be considered as "known" costs.

o In order to obtain return-on-investment factors that accurately describe the sample, each programs' contribution must be weighted by the ratio of its dollar value to the total dollar value of the sample. For example, there may be programs whose procurement-to-development cost factor is 40, but whose

ENCLOSURE (1)

impact on the overall factor is minimal because that program's R&D dollar value represented only one percent of the total sample's dollar value.

o The NAVCOMPT analysis considered only total procurement and total R&D costs. The possible affect of unit cost and production quantities was not analyzed. A more extensive study of procurement and R&D cost relationships should consider the impact of a large production quantity or a production run over a long period of time.

2

SAMPLE PROGRAMS

| 1<br>Program | 2<br>P/R | 3<br>FY 79 AMT<br>($ in M's) | 4<br>Fraction<br>of Sample | 5<br>Weighted<br>Factor |
|---|---|---|---|---|
| F-18 | 5.6 | 473.6 | .42 | 2.35 |
| Lamps III | 4.7 | 124.5 | .11 | .52 |
| TACTAS | 8.1 | 25.2 | .02 | .16 |
| HARM | 4.8 | 43.4 | .04 | .19 |
| TOMAHAWK | 1.8 | 152.1 | .13 | .23 |
| STD MSL IMP | 3.5 | 49.1 | .04 | .14 |
| TRIDENT I MSL | 2.2 | 191.8 | .17 | .37 |
| SURTASS | 5.3 | 6.6 | .006 | .01 |
| ASPJ | .6 | 10.2 | .009 | .01 |
| MCLWG | 3.7 | 1.9 | .002 | .01 |
| ABN ASW Pods | 5.7 | 1.0 | .001 | .01 |
| Adaptive BOM | 4.4 | 5.8 | .005 | .02 |
| SPN-42 RADAR | 4.5 | 3.2 | .003 | .01 |
| Spec W/F Craft | .6 | 6.0 | .005 | .01 |
| ADV RADAR WARNING | 33.2 | .6 | .0005 | .02 |
| Helo Night Vision | 11.8 | 5.5 | .005 | .06 |
| Air-Air MSL SYS | .4 | 28.5 | .03 | .01 |
| CIC CONV | 8.0 | 7.1 | .006 | .05 |
| | | 1136.4 | 1.000 | 4.20 |

FY 79 Weighted Multiplier (Procurement to R&D)= 4.2

Page 1 of 2 TAB 1

SAMPLE PROGRAMS -- LEGEND

| COLUMN | DESCRIPTION |
|---|---|
| 1 | Program short title |
| 2 | Ratio of total procurement costs to total R&D costs |
| 3 | Amount of dollars budgeted in the FY 79 RDT&EN budget |
| 4 | Fraction representing each programs' share of the total sample |
| 5 | Weighted procurement-to-development factor obtained by multiplying columns 2 and 4 |

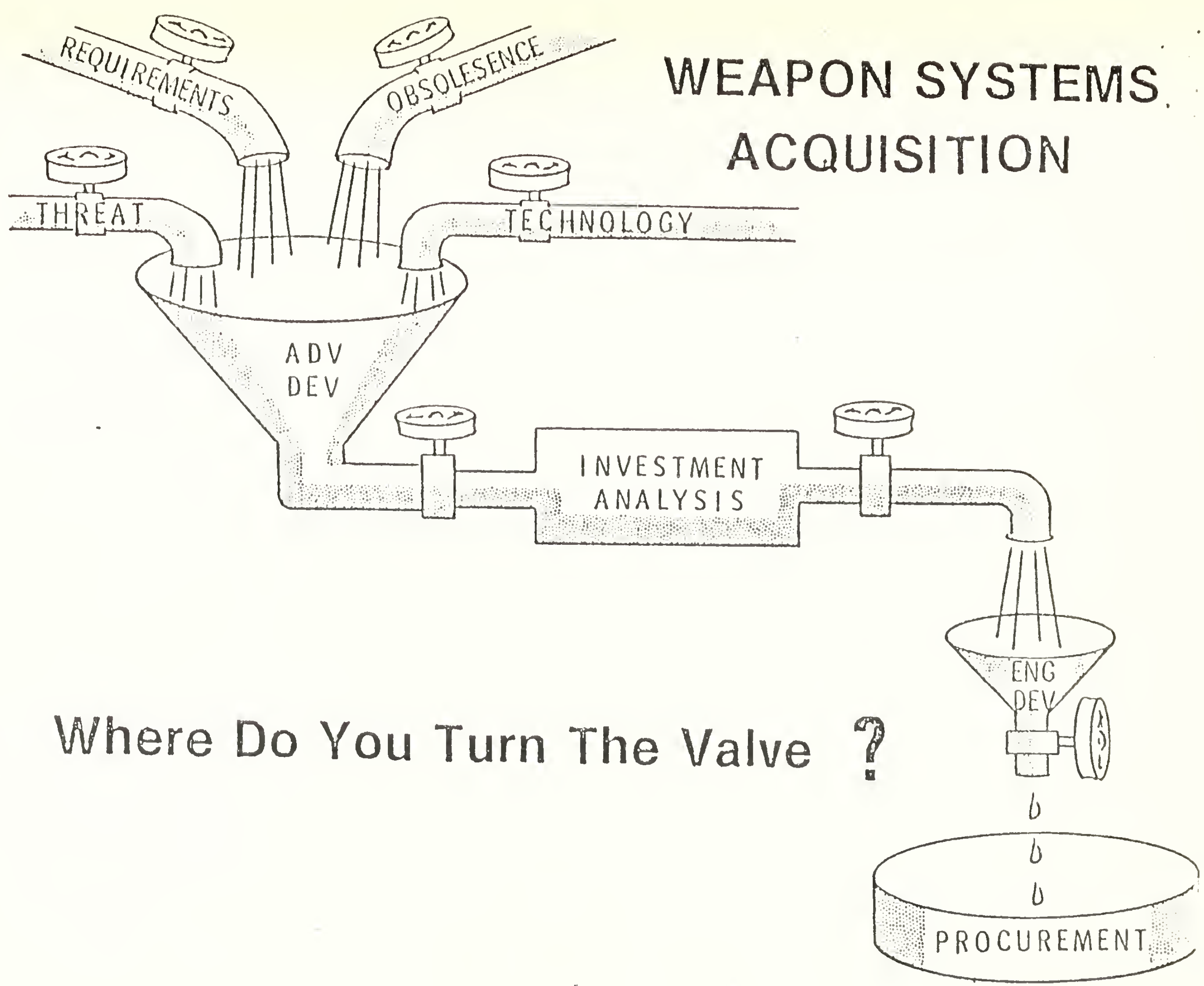
## R&D COST OF
## PROGRAMS IN ENGINEERING DEVELOPMENT
### (IN BILLIONS OF DOLLARS)

| FY 79 BUDGET | COST TO COMPLETE DEVELOPMENT | TOTAL R&D FY 79-83 |
|---|---|---|
| $1.6 | $3.9 | $5.5 |

## ESTIMATED PROCUREMENT COST OF R&D PROGRAMS IN ENGINEERING DEVELOPMENT

(IN BILLIONS OF DOLLARS)

| COST OF PROGRAMS PRICED OUT | PROJECTED COST OF REMAINING PROGRAMS | TOTAL ESTIMATED PROCUREMENT COST |
|---|---|---|
| $27.5 | $8.5 | $36 |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REQUIREMENTS
OBSOLESENCE
THREAT
TECHNOLOGY
ADV
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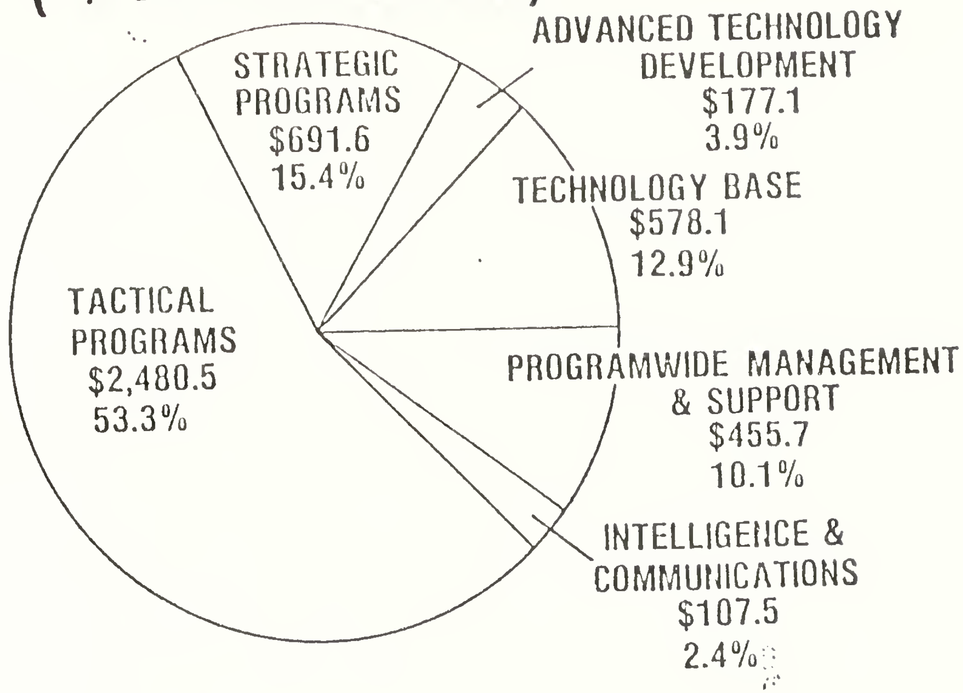
ANALYSIS
ENG
DEV
PROCUREMENT
Where Do You Turn The Valve ?

# RESEARCH, DEVELOPMENT, TEST & EVALUATON, NAVY FY 1979 ( $ IN MILLIONS)




| FY 1978 | FY 1979 | △ |
|---|---|---|
| $4,021.8 | $4,490.5 | $ + 468.7 |

## RESEARCH, DEVELOPMENT, TEST AND EVALUATION, NAVY
## ($ MILLIONS)

| | FY 1977 | FY 1978 | FY 1979 |
|---|---|---|---|
| | **$3,800.1** | **$4,027.8** | **$4,490.5** |
| PROGRAM HIGHLIGHTS | | | |
| F-18 A/C | 340.6 | 625.1 | 473.6 |
| TRIDENT MISSILE | 568.1 | 332.7 | 206.8 |
| TRIDENT SUBMARINE | 75.3 | 68.6 | 58.8 |
| FBM SYSTEMS | 113.0 | 129.8 | 135.9 |
| TOMAHAWK MISSILE | 106.8 | 210.3 | 143.1 |
| LAMPS III | 72.1 | 106.4 | 124.3 |
| AV8B A/C | 33.6 | 59.8 | 85.6 |
| CSEDS | 82.8 | 35.5 | 37.2 |
| STANDARD MISSILES | 17.8 | 19.5 | 58.6 |
| SSBM SECURITY | 29.8 | 37.9 | 37.2 |
| VSTOL A/C DEVELOPMENT | 12.4 | 22.5 | 52.5 |
| HARM | 30.0 | 29.7 | 43.4 |
| ADVANCED ASW TORPEDO | 25.4 | 25.0 | 44.3 |
| ELF COMMUNICATORS | 14.8 | 15.0 | 40.5 |

## APPENDIX B

## GLOSSARY OF TERMS AND ABBREVIATIONS

Adjusted regression - An ordinary least squares regression which has been corrected for the serial correlation of the error terms [Refs. 10 and 12].

APN - Appropriation title; Aircraft Procurement, Navy [Ref. 8].

Appropriation - An annual authorization by Act of Congress to incur obligations for specified purposes and to make payments out of the Treasury. Synonyms: budget authority and new obligational authority [Ref. 5].

Authorization - Substantive law which must be passed by Congress prior to any appropriation which specifies the amount and purposes for which money may be used. This requirement, which originally applied only to procurement of aircraft, missiles, and ships, has been expanded year-by-year to other categories until now it includes procurement of tracked combat vehicles and other weapons, RDT&E, military construction, torpedoes, reserve and active duty personnel strength [Ref. 4].

Autoregression - A condition in which the error terms from different observations are correlated; the effect of an error disturbance in one period carries over into another period. Synonym: serial correlation [Refs. 10 and 12].

Budget activity - The major subdivisions of each budget appropriation account as submitted to and approved by Congress (e.g., the budget activities as of fiscal year 1974 for the RDT&E,N appropriation are: Technology base, advanced technology development, strategic programs, tactical programs, intelligence and communications, program-wide management and support) [Ref. 2].

Budget authority - An annual authorization by act of Congress to incur obligations for specific purposes and to make payments out of the Treasury. Synonyms: appropriation, new obligational authority [Ref. 7].

Budget plan - That portion of the programming-and-financing section of the Federal budget request which shows by budget activity the amounts for procurement actions programmed and the manner in which the total amount is being financed [Refs. 7 and 8].

Budget year - The current fiscal year plus one [Ref. 5].

Budgeting - The process of translating approved resource requirements (manpower and material) into time-phased financial requirements [Ref. 5].

Constant dollars - Costs expressed in terms of the price levels prevailing in the base year (FY 1979 in this case) [Ref. 5].

Crosswalking - The process of transforming or translating the budget from DOD program category to appropriation budget activity and vice versa [Ref. 1].

Current dollars - Costs expressed in terms of the price levels prevailing when those costs were incurred, obligated, and/or expended [Ref. 5].

DOD program category - One of the ten major program categories outlined by the Department of Defense which are objective-, goal-, mission-, and/or output-oriented [Ref. 4].

Econometrics - The development and use of mathematical models representing portions of the real world [Ref. 12].

Economic forecasting - The quantitative estimation about the likelihood of future events based on past and current information [Ref. 12].

Ex post forecast - A quantitative estimation about the likelihood of an event during a past time period when the value of both explanatory and dependent variables are known with certainty [Ref. 12].

Expenditure - A charge against available funds which represent the actual payment of cash. Synonym: outlay [Ref. 5].

New obligational authority (NOA) - An annual authorization by Act of Congress to incur obligations for specified purposes and to make payments out of the Treasury. Synonym: appropriation, budget authority [Ref. 5].

Obligation - A legal reservation of a specified amount of an appropriation for expenditure [Ref. 5].

OPN - An appropriation title: Other Procurement, Navy [Ref. 8].

Ordinary least squares (OLS) regression - A procedure for determining the statistical relationship between two variables by calculating the equation for a straight line which minimizes the sum of the squared deviations (observed-calculated) of the dependent variable [Ref. 11].

Outlay - A charge against available funds representing the actual payment of cash. Synonum: expenditure [Ref. 7].

PAMN - An old appropriation title: Procurement of Aircraft and Missiles, Navy. (This appropriation was divided into APN and WPN in 1974) [Ref. 8].

PMC - An appropriation title: Procurement, Marine Corps [Ref. 8].

Program - A plan or scheme of action designed for the accomplishment of a definite objective which is specific as to the time-phasing of the work to be done and the means proposed for its accomplishment, particularly in quantitative terms, with respect to manpower, material, and facilities requirements. Provides the basis for budgeting [Ref. 5].

Program years - The four fiscal years beyond the budget year [Ref. 5].

Programming - The progcess of translating planned military force requirements into time-phased manpower and material resource requirements [Ref. 5].

$R^2$ statistic - A statistic which represents the goodness of fit of the line provided by the regression procedure versus the observed occurrence [Ref. 11].

RDT&E,N - An appropriation title: Research, Development, Test and Evaluation, Navy [Ref. 8].

Reimbursable - An amount added to the total direct program which reflects the value of activity conducted in support of other governmental agencies or programs [Ref. 7].

Reimbursements - When authorized by law, amounts collected for materials or services furnished to the public or other government agencies [Ref. 7].

Selected Acquisition Report (SAR) - A report prepared for the Secretary of Defense which summarizes current estimates of technical, schedule, and cost performance of Navy development and procurement programs in comparison with original plans and the current program [Refs. 3 and 6].

Serial correlation - The error terms from different observations are correlated; the effect of an error disturbance in one period carries over into another period. Synonym: autoregression [Refs. 10 and 12].

Time-series data - Observations of the value of explanatory and dependent variables which are collected over time [Ref. 12].

Total direct program - The total value of actions programmed in direct support of the budget activities making up an appropriation. Synonum: total obligational authority (TOA) [Ref. 8].

Total Obligational Authority (TOA) - The total amount of funds available for programming in a given year, regardless of the year the funds are appropriated, obligated, or expended. It includes new obligational authority, unprogrammed obligational authority from prior years, reimbursements not used for replacement of inventory in kind, advance funding for programs to be financed in the future, and unobligated balances transfered from other appropriations. Synonym: total direct program [Ref. 5].

WPN - An appropriation title: Weapons Procurement, Navy [Ref. 8].

## APPENDIX C - DATA TABLE (1000's) [Ref. 8]

| Category | FY62 | FY63 | FY64 | FY65 | FY66 | FY67 |
|---|---|---|---|---|---|---|
| RDT&E,N (Current $) | 1318905 | 1503887 | 1565230 | 1423366 | 1582457 | 1947442 |
| DOD Deflator | 43.9582 | 44.3135 | 45.9732 | 46.1035 | 47.4930 | 49.1593 |
| * RDT&E,N (Constant FY 79 $) | 3025136 | 3393745 | 3472640 | 3087327 | 3331979 | 3961493 |
| Rounded Off (Millions) | 3025 | 3394 | 3473 | 3087 | 3332 | 3961 |
| PAMN/APN (Current $) | 3140241 | 3058029 | 2712071 | 2613309 | 3564360 | 3865306 |
| DOD Deflator | 45.9904 | 46.3855 | 47.2275 | 48.6782 | 50.3603 | 52.0849 |
| * PAMN/APN (Constant FY 79 $) | 6828036 | 6592640 | 5742567 | 5368541 | 7077718 | 7421164 |
| WPN (Current $) | | | | | | |
| DOD Deflator | | | | | | |
| *WPN (Constant FY 79 $) | | | | | | |
| SCN (Current $) | 2590015 | 2635445 | 2088258 | 1815389 | 1875956 | 2175595 |
| DOD Deflator | 24.0430 | 25.1076 | 26.5571 | 28.7531 | 31.1050 | 33.8431 |
| *SCN (Constant FY 79 $) | 10772429 | 10496603 | 7863276 | 6313716 | 6031043 | 6428474 |
| OPN (Current $) | 870779 | 908992 | 1133771 | 1240797 | 2034167 | 2334469 |
| DOD Deflator | 45.9963 | 46.4283 | 47.2571 | 48.6736 | 50.3478 | 52.0919 |
| *OPN (Constant FY 79 $) | 1893150 | 1957840 | 2399155 | 2549220 | 4040230 | 4481443 |
| PMC (Current $) | 276835 | 265853 | 207598 | 168000 | 767600 | 542300 |
| DOD Deflator | 45.1000 | 45.7327 | 46.7602 | 48.2212 | 49.9034 | 51.6974 |
| *PMC (Constant FY 79 $) | 613825 | 581319 | 443963 | 348394 | 1538172 | 1048989 |
| TOTAL PROCUREMENT (Constant FY 79 $) | 20107440 | 19628402 | 16448961 | 14579871 | 18687163 | 19380070 |
| ROUNDED OFF (Millions) | 20107 | 19628 | 16449 | 14580 | 18687 | 19380 |

*(Constant FY 79 $) = (Current $) ÷ DOD Deflator x 100

## APPENDIX C - DATA TABLE (1000's) [Ref. 8]

| Category | FY 68 | FY 69 | FY 70 | FY 71 | FY 72 | FY 73 |
|---|---|---|---|---|---|---|
| RDT&E,N (Current $) | 1886250 | 2191541 | 2271919 | 2212001 | 2411109 | 2541604 |
| DOD Deflator | 51.2022 | 53.7742 | 56.6423 | 59.4917 | 62.3895 | 66.1719 |
| *RDT&E,N (Constant FY 79 $) | 3683924 | 4075451 | 4010994 | 3718167 | 3864607 | 3840911 |
| Rounded Off (Millions) | 3684 | 4075 | 4011 | 3718 | 3865 | 3841 |
| PAMN/APN (Current $) | 3340538 | 3157066 | 2831030 | 3343064 | 3983000 | 3672509 |
| DOD Deflator | 53.9310 | 56.0717 | 58.4445 | 60.9120 | 63.9769 | 68.0851 |
| *PAMN/APN (Constant FY 79 $) | 6194096 | 5630409 | 4843963 | 5488350 | 6225685 | 5393998 |
| WPN (Current $) | | | | | | |
| DOD Deflator | | | | | | |
| *WPN (Constant FY 79 $) | | | | | | |
| SCN (Current $) | 1231650 | 1070041 | 2464087 | 2356480 | 3010200 | 2962400 |
| DOD Deflator | 36.6967 | 39.6104 | 43.9544 | 49.5569 | 56.5394 | 62.9695 |
| *SCN (Constant FY 79 $) | 3356296 | 2701414 | 5606008 | 4755100 | 5324075 | 4704500 |
| OPN (Current $) | 2301149 | 2429227 | 1993190 | 1678011 | 1769889 | 2302170 |
| DOD Deflator | 53.9517 | 56.0621 | 58.4365 | 60.9538 | 64.0874 | 68.0960 |
| *OPN (Constant FY 79 $) | 4265202 | 4333100 | 3410865 | 2752923 | 2761680 | 3380771 |
| PMC (Current $) | 779900 | 645300 | 547200 | 249426 | 128100 | 182200 |
| DOD Deflator | 53.6040 | 55.7560 | 58.2066 | 61.0921 | 64.5106 | 68.7605 |
| *PMC (Constant FY 79 $) | 1454929 | 1157364 | 940100 | 408279 | 198572 | 264978 |
| TOTAL PROCUREMENTS (Constant FY 79 $) | 15270523 | 13822287 | 14800936 | 13404652 | 14510012 | 13744247 |
| ROUNDED OFF (Millions) | 15271 | 13822 | 14801 | 13405 | 14510 | 13744 |

*(Constant FY 79 $) = (Current $) ÷ DOD Deflator x 100

## APPENDIX C - DATA TABLE (1000's) [Ref. 8]

| Category | FY 74 | FY 75 | FY 76 | FY 77 | FY 78 | FY 79 |
|---|---|---|---|---|---|---|
| RDT&E,N (Current $) | 2704473 | 3051614 | 3314320 | 3800055 | 4021791 | 4490500 |
| DOD Deflator | 72.0286 | 78.3905 | 83.0479 | 88.4412 | 94.2814 | 1.00000 |
| *RDT&E,N (Constant FY 79 $) | 3754721 | 3892837 | 3990853 | 4296702 | 4265731 | 4490500 |
| Rounded Off (Millions) | 3755 | 3893 | 3991 | 4297 | 4266 | 4491 |
| | | | | | | |
| PAMN/APN (Current $) | 2936641 | 2777319 | 2977800 | 2931600 | 3552900 | 4078800 |
| DOD Deflator | 73.3651 | 78.2962 | 83.2543 | 89.6127 | 94.3985 | 1.00000 |
| *PAMN/APN (Constant FY 79 $) | 4002777 | 3547195 | 3576752 | 3271411 | 3746224 | 4078800 |
| | | | | | | |
| WPN (Current $) | 806619 | 738700 | 1120500 | 2002300 | 2293300 | 2047500 |
| DOD Deflator | 73.0793 | 78.1249 | 83.1075 | 89.4623 | 94.7857 | 1.00000 |
| *WPN (Constant FY 79 $) | 1103759 | 945537 | 1348354 | 2238149 | 2419458 | 2047500 |
| | | | | | | |
| SCN (Current $) | 3508400 | 3111400 | 3954181 | 5700400 | 5802500 | 4712400 |
| DOD Deflator | 69.6217 | 75.8109 | 81.3147 | 88.2123 | 93.9760 | 1.00000 |
| *SCN (Constant FY 79 $) | 5039233 | 4104159 | 4862812 | 6462137 | 6174449 | 4712400 |
| | | | | | | |
| OPN (Current $) | 1375301 | 1569622 | 1837651 | 2198739 | 2186410 | 2708600 |
| DOD Deflator | 73.1864 | 78.1998 | 83.1819 | 89.5082 | 94.7841 | 1.00000 |
| *OPN (Constant FY 79 $) | 1879176 | 2007194 | 2209196 | 2456467 | 2306727 | 2708600 |
| | | | | | | |
| PMC (Current $) | 207732 | 216100 | 279618 | 321674 | 450200 | 371900 |
| DOD Deflator | 73.6866 | 78.5933 | 83.4911 | 89.6990 | 94.8486 | 1.00000 |
| *PMC (Constant FY 79 $) | 281913 | 274960 | 334908 | 358615 | 474651 | 371900 |
| | | | | | | |
| TOTAL PROCUREMENT (Constant FY 79 $) | 12306858 | 10879045 | 12331922 | 14786779 | 15121509 | 13919200 |
| ROUNDED OFF (Millions) | 12307 | 10879 | 12332 | 14787 | 15122 | 13919 |

*(Constant FY 79 $) = (Current $) ÷ DOD Deflator x 100

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